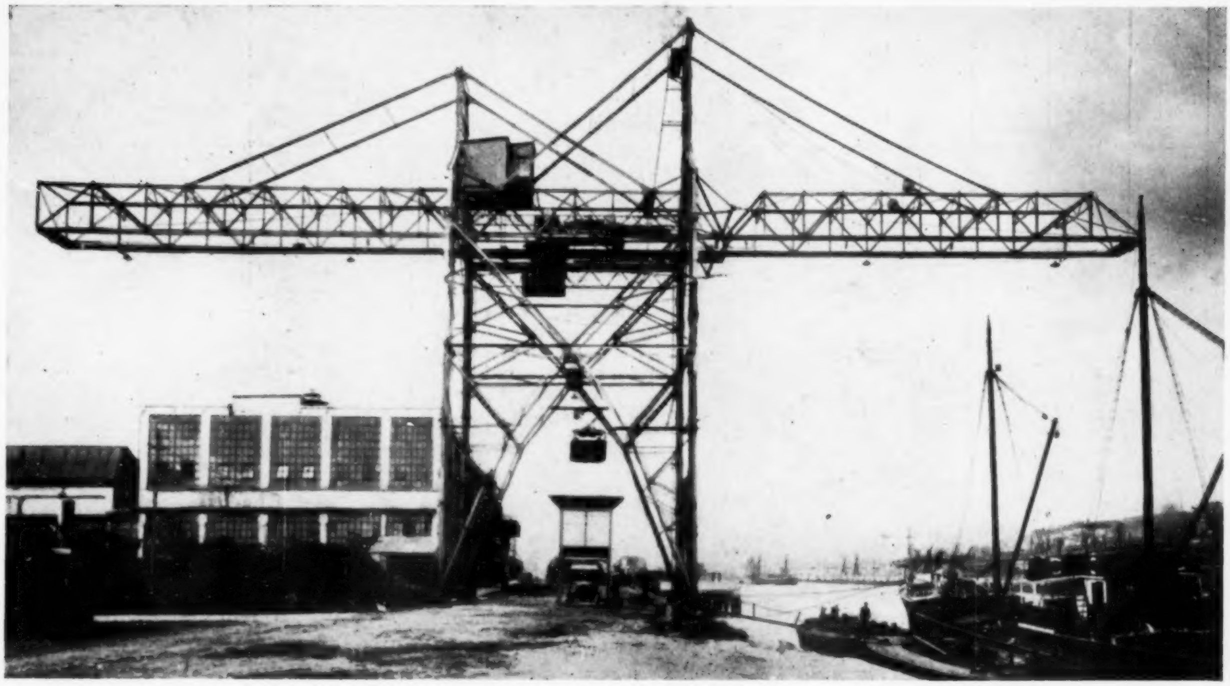


5-ton Crane.—Fig. 1.

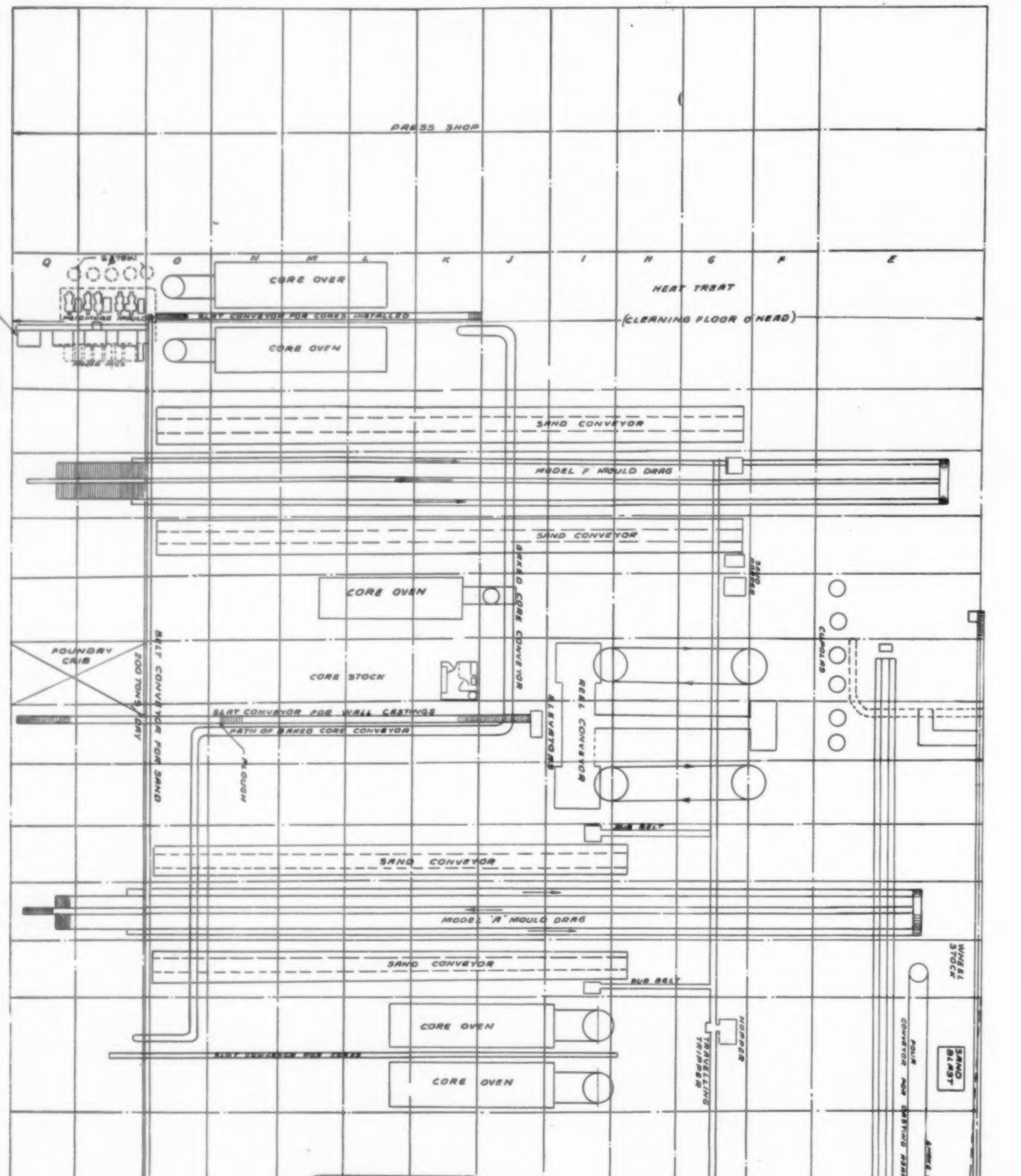
The Ford Foundry at Cork

AT the Cork works of Ford Motors (England), Ltd., are made the Fordson tractors for the markets of the whole world, and in the foundry all the castings are made for these, and also for the Ford cars that are manufactured at the company's works at Trafford Park, Manchester. The immensity of the Cork works can be appreciated when it is stated that in the foundry alone over 1,300 men are employed. The organisation of the works is quite exceptional.

Not only are high wages paid to the workmen, but every factor that will reduce fatigue, and consequently increase production, is taken into account; a feature of the organisation, for instance, being that machines and tables are so arranged that there is no bending, operations being done at the most convenient height to reduce the expenditure of energy. The normal work hours are eight per day for five days per week. Manufacturing methods are so carefully thought out that, while foundry practice as regards sand, metal, and operations are scientific and up to date, unskilled men are moulding the most complicated castings a few days after they have entered the foundry. It is a triumph of correct production planning. Apart altogether from laboratory tests, a careful examination of the castings produced indicates that they are homogeneous and apparently free from blowholes and sponginess. At the Ford foundry the workmen are manual workers in the sense that their methods are thought out for them, and what they have to do is to translate a production system into terms of tons of castings. At any part of the foundry, for instance, if a machine or conveyor goes wrong there is a compressed-air system, and the operator can give one blast which brings the electrician if the electrical side has failed, and two blasts if the breakdown is mechanical; on no account must a moulder or other foundry worker endeavour to effect repairs or even adjustments.

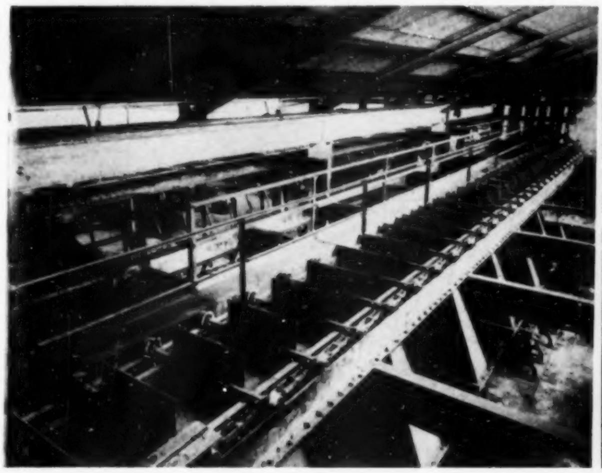
Such important changes have been made in the general layout of the Ford foundry recently that it is, in effect, a new foundry. Even now reconstruction has not been completed, and alterations of an important kind are in progress. The illustration at the head of the article, Fig. 1, shows an end view of part of the foundry. An extension is being erected on this end, and beyond this will be the foundry store yard for pig iron, sand, etc. This store will be commanded by two 50-ft. span electric travelling cranes, which will store the material landed by the transporter crane, and also feed the raw materials to the different conveyors, to take them to the charging floor and hoppers. With regard to layout and the relative positions of the several core and mould conveyors, core ovens, cupolas, and charging platform, these are clearly shown on the accompanying illustration Fig. 2. The visitor to the foundry is impressed with the amount of new plant that is being installed. It is apparently an axiom of the Ford firm that what is a perfect production plant to-day may

Core Oven.



General Layout of Ford Foundry.—Fig. 2.

not be to-morrow, and so there is no hesitation in scrapping a machine that is comparatively new if it has been superseded by an improved one. At the present time a conveyor is being contemplated for conveying castings to the machine shop, where they would be picked off the conveyor at whatever machine they are required. An overhead chain conveyor passes the ends of the casting conveyors, where the hot castings are hooked on, and having carried these to and fro several times outside the building, it finally brings them to the cleaning floor for tumbling and fettling. This chain being continuous and always travelling, there are no castings on the floor for cooling.

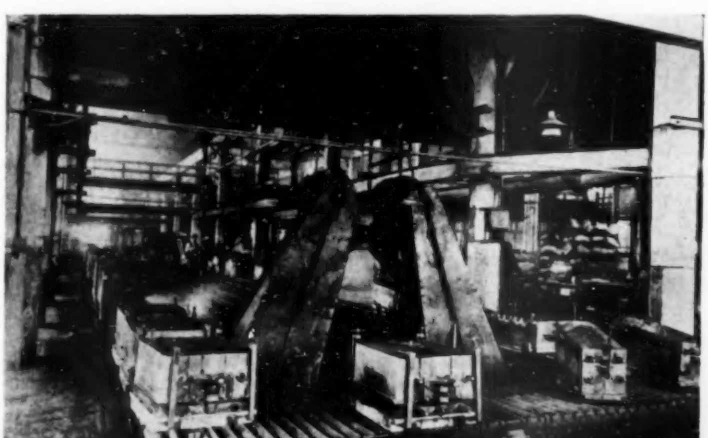


Sand Conveyors.

Sand Conveyor.

An essential and important fact of the organisation is that dealing with the overhauling and repairing of equipment. In the foundry there are 25 patternmakers, who are no longer patternmakers in the proper sense, but are simply foundry-equipment men. If a moulding machine is not functioning properly, or anything goes wrong with the pattern-plate equipment of the machine, it is their business to put it right.

The pattern shop is a very interesting department. In addition to wood patternmakers there are a number of metal patternmakers. The usual practice is to make an aluminium master pattern from a wood pattern, then cast patterns in iron from it. An interesting feature of the pattern-shop practice is that aluminium layouts are made of all patterns, and these constitute what are, in effect, permanent workshop drawings. These aluminium lay outs are stored in racks, the metal templates that are used in shaping and finishing patterns are also stored, so that they can be used over and over again as required. In the metal-pattern shop the bench-man takes his work to the machine-man. For metal-pattern finishing Cincinatti vertical millers are installed, and machines that are of the greatest value for the work are a number of Keller die - sinking machines, made by the Keller Mechanical Engineering Corporation, of New York ; while a grinding machine is installed in the pattern shop with a special rig for grinding the faces of moulding-boxes.



Extension of existing Drag Conveyor. North End.

As will be explained more fully later, all the moulds in the foundry are made of greensand, with the exception of a proportion of the pistons that are made by an ingenious permanent mould system. There is a moulding machine with a number of permanent moulds in a circle around a central spindle, which is automatically closed. The sequence of operations are blacking the mould with acetylene lamp, placing the cores, when the moulds are automatically closed ; pouring the metal, knocking-out castings, and the mould is cooled with a jet of compressed air. A permanent-piston mould is good for about 10,000 castings.

There is scientific treatment of all raw materials. Coke is discharged from steamers to bins over charging floor, and the pig iron is conveyed to the charging floor, and the charge is weighed on scales. There are six cupolas, two 70-in. cupolas having been installed recently. For controlling the supply of air to each cupola a pressure-gauge and volume-recorder are used. The pressure-gauge is of the usual water-column type, showing pressure in ounces. For showing the volume of air entering the cupola the Wilson blast recorder is used.

Test-bars of the different grades of iron are taken at intervals, and these are sent to the laboratory, where they are tested for physical and chemical properties. The test-bar is first broken in an Olsen transverse testing machine, which gives an autographic chart, showing the breaking load on 12-in. span and the central deflection. Drillings are taken from one-half of the broken bar for chemical analysis. The other half of the bar can be used for tensile test, which is performed on an Olsen Universal testing machine. Hardness is measured on the Standard Brinell testing machine. The proportions of the

charge are then altered to check the tendency to vary from specification. It will thus be seen that nothing is left to chance, and the foundry practice, in a metallurgical sense, approximates as closely to chemistry conditions as is practically possible.

The tendency in recent years has been for all buying of foundry pig iron to be to analysis, instead of by fracture as formerly. At the Ford foundry all the pig iron is purchased to analysis, three different grades of iron being bought, from which the different grades of iron are produced by varying the proportions of pig, scrap iron, and steel. The analyses specified are as follows :—

	No. 1.	No. 2.	No. 3.
Silicon	2·75–3·25	2·50–3·00	2·00–2·50
Sulphur.. ..	0·050 max.	0·050 max.	0·050 max.
Phosphorous..	0·40–0·60	0·12–0·20	0·75–0·95
Manganese ..	0·60–1·00	0·60–1·00	0·60–1·00

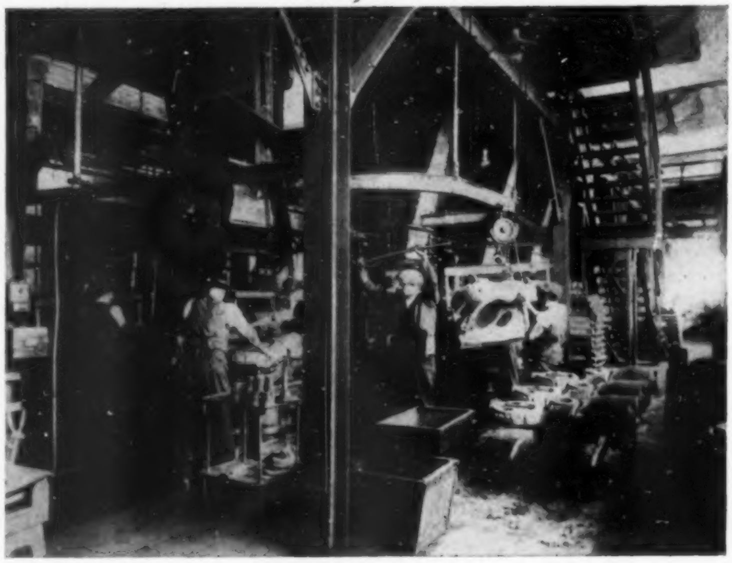
The table below shows the grades of iron used in the foundry, and the analysis of each.

Type.	% of Steel.	Silicon.	Sulphur.	Phosphorous.	Manganese.	Carbon.
			Max.			
"A"	15	1·80–2·10	0·100	0·27–0·33	0·60–0·80	3·20–3·50
"AA"	15	2·30–2·60	0·100	0·27–0·33	0·60–0·80	3·20–3·50
" B "	—	2·50–2·90	0·100	0·42–0·48	0·60–0·80	3·40–3·70
" P "	5	2·40–2·60	0·100	0·32–0·38	0·60–0·80	3·30–3·60

Grade A iron is used for cylinder blocks, transmission housing, and all parts requiring the strength of semi-steel ; while grade AA is similar to A, but has higher silicon percentage, and is used for cylinder head, crank-case, and parts of light section requiring strength. Grade B iron is used for die-cast pistons, and grade P is piston-ring iron.

With regard to coke, this is also purchased to sample and analysis, which is specified as follows :—

Carbon ..	88% or over
Ash ..	6% or under
Sulphur ..	8% or under
Size ..	2½ in. and over



Moulding Transmission Housing.

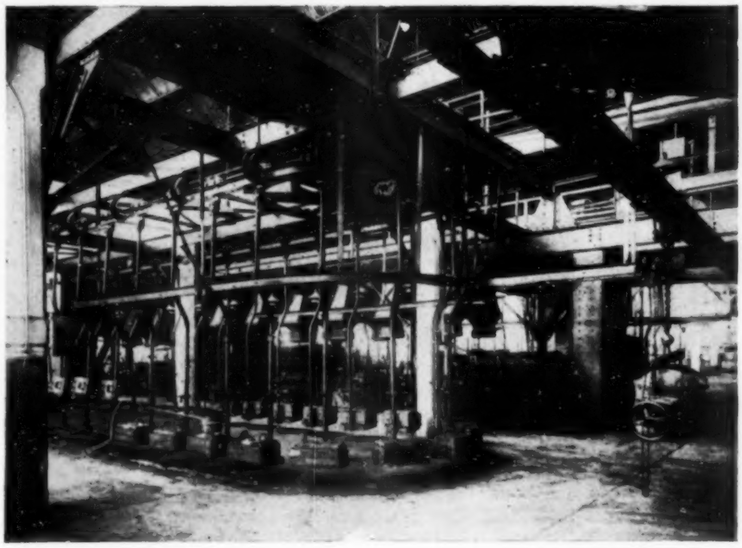
The greatest possible attention is given to the correct conditioning of the sand, and sand being supplied to the operators is tested frequently for moisture and permeability. The principle of the moisture meter used is based on the difference in electrical conductivity between dry and wet sand. On the head of the instrument a small ammeter is mounted. The leg of the instrument, which is about 3 ft. long, consists of a hollow tube, which houses a number of small dry batteries. These are connected in series and in circuit with the ammeter. The two ends of the circuit are connected to two exposed terminals at the foot of the tube. When the tube is inserted in the sand to be tested, the deflection of the ammeter pointer depends on the resistance of the sand between these terminals. The ammeter is calibrated to read in per cent. of moisture. The meter for testing permeability is shown in Sketch.

Heap sand is tested as tempered for the moulders. A good representative sample is obtained by taking small portions from different parts of the heap. This sample is put at once into a two-quart pail, with close-fitting top, which is adjusted so as to prevent sand from drying out. The sample is then passed twice through a riddle, preferably eight-mesh, and returned to the pail, the cover being replaced. The procedure in testing is somewhat complicated, but a little practice makes it a very rapid one, and if both heap and facing sands are tested regularly a reliable measure of the openness of the sand will result. If the sand is too tight, it may be due to excessive moisture, and to check this it is best to dry it out, divide it into several portions, and temper to different degrees, then to test each portion after it has been allowed to stand long enough to get even-tempered. Some sands tighten up considerably if a little too wet. A half-dozen two-quart covered tin pails are the best containers to handle samples, as they are practically air-tight and reduce drying-out of sand.

Cylinder Block and Heavy-Casting Conveyor.

In order to determine accurately the venting power or permeability of new sand, it is best to dry out a good representative sample and divide into several portions. Temper each portion to a different degree, depending on whether the sand is heavily bonded or lightly bonded. After tempering, riddle once through a No. 8 (use a No. 4 if gravelly sands are used), place in a pail,

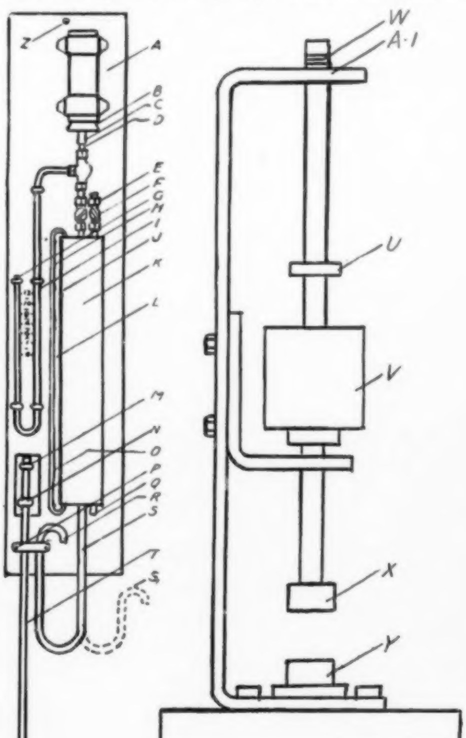
put cover on tight, and let it stand for a few hours to equalise the temper. Then test in similar manner as for heap sands. This test will show how much the sand closes



Small Casting Conveyor.

up with excessive temper, and will show at what temper it has the most open structure after ramming. Sands differ a good deal from each other in this respect.

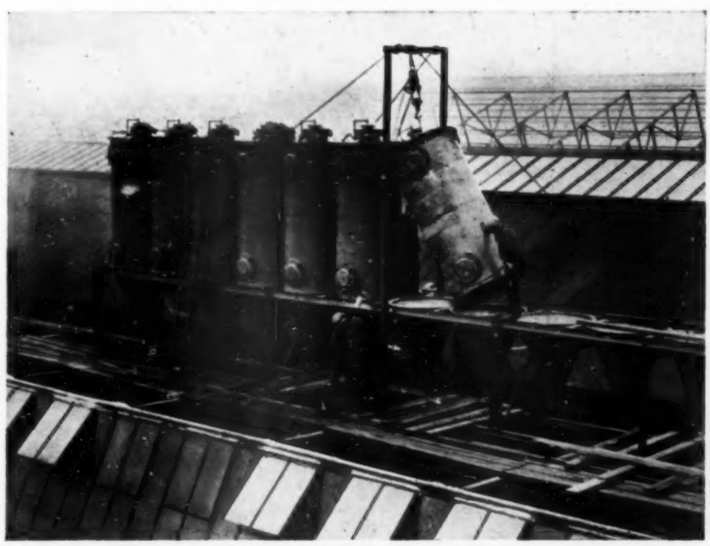
For lightly bonded sands it is well to temper different portions to 6, 8, 10, and 12% moisture, respectively; while for heavily bonded sands 8, 10, 12, and 14% is recommended. For tempering in this way the use of an inexpensive trip balance is recommended, with a set of metric weights for weighing the dry-sand portions, and a glass



tube, graduated in metric system, for accurately measuring the tempering water to any percentage desired. For extensive testing of sands, as in research work, a stop-watch, graduated in decimals, will pay for itself quickly in measuring the vent.

Moulding flasks are standardised in the foundry for most work. This would not be possible in a general jobbing foundry, but it is the most efficient method in this foundry, where the same sizes of repetition castings are made all the time. The firm does not make its own moulding-boxes, and it is of interest that as the weight of the flasks has an important bearing on production because of the fatigue factor, the method of purchase is by weight per flask, and they are all made of steel. The moulding-box pins are made and located to $\frac{1}{200}$-in. limits, and whenever joint surfaces show any sign of wear they are returned to the pattern shop to be reground.

We may now consider, briefly, moulding methods in the foundry. As already indicated, practically all the castings in the Ford foundry are made by the green-sand method, and even a proportion of the pistons are made in green-sand. There is, of course, no floor or bench moulding, and various types of machines are used. There is a number of Nicholls' combination jolt, squeeze, and draw machines, and on each of these machines over 100 moulds are made per hour during the eight-hours working day, and in some cases up to 120 moulds per hour. From one pattern the number of cylinder blocks that are made in eight hours is in the neighbourhood of 230, and this is the average production during the eight-hour day. The first cast begins at 8-15 a.m., and there is continuous casting all day afterwards. For cylinder blocks, Osborne roll-over machines are used for the drags, and Pridmore strippers for the copes. It may be of interest to describe the process of moulding cylinder blocks. The moulding squad on drag parts consists of three men, whom we may designate by the letters A, B, and C. To avoid monotony, and also to prevent one man doing more than his share of actual lifting, the three men in a squad change over frequently. A and B lift the flasks from the pile behind the moulding machine, and C stamps the mould with the letter of the man responsible for ramming the mould, because every man on a mould conveyor has his own letter-stamp. A then places the port



Dust Extractors for cleaning floors shown in course of construction.

and valve cores and takes over the mould to black and finish it, when A and B lift it to the conveyor to be taken to the casting floor. Date discs are also stamped on the

(*Continued on page* 8.)

Executive Observations on General Gas-Producer Practice

By WALTER LISTER.

A fitting preliminary to a series of articles on Errors in Steelmaking to appear in subsequent issues.

THE gas-producing plant is one of the most important parts of a melting-shop equipment, but even in these days it is rather astonishing to find that in many places the gas plant is only a secondary consideration from the point of view of steel production. One finds the absurd anomaly still existing of attempts being made to work modern furnaces with obsolete gas equipment. Old-fashioned furnaces are pulled down and new and larger ones erected, but the old gas plant is still expected to carry on, and in some miraculous manner shake off the decline of years and come up to the scratch with vigorous youth in the shape of new and more scientific ideas.

A steelworks run on these lines has no chance to-day. Besides, it is not fair to the men who have to do the work. Give a gas-man good plant, and he can be reasonably expected to make good and sufficient gas for the melter, who can then have no excuse for not turning out good metal. This is the first and most important observation. The next is: given good gas, make the best use of it. Good plant may be of either the static or revolving type, but errors of working are liable to occur in both; they each require men of more skill and intelligence than was thought necessary in the old days. Therefore it is absolutely necessary to have gas-men who can understand a little of the chemical reactions that take place inside a producer.

Men who don't know should be taught. At the present time it is safe to say that not more than 25% of the men employed in making gas have any idea how that gas is obtained. A lot of errors can be avoided if producers are mechanically fed, but this does not imply that good gas cannot be made from hand-fed producers. The advantage of a mechanical feed is that the foreman (who is naturally the most intelligent and should possess the most knowledge and skill) can regulate the flow of coal from the hopper according to the type of coal he is dealing with.

LOW FIRES A COMMON FAULT.

With hand-fired producers the amount of coal charged is left more or less to the discretion of the gas-men themselves, who may or may not be educated sufficiently to understand the relation of the fuel bed to the quality of gas made. A common fault with gas-men is to keep the fires too low. Low fires are usually very hot, and when a feed of coal is put down a spectacular rush of gas ensues: all very nice. But this lasts only for a few minutes, and is generally timed for when the foreman comes along. Again, low fires are easier to clean. But consideration for the cleaners should never be allowed to interfere with the quality of the gas.

Good gas cannot be made with low, hot fires. It will contain too large a quantity of carbon dioxide (CO_2) because the fuel bed will be too thin to decompose all the air and steam blown in. Figs. 1 and 2 will explain this. Carbon dioxide is non-combustible and useless.

With thin fires practically the only part of the gas which is combustible is the volatile hydrocarbons driven off immediately the feed of coal is put down. Moreover, channels are more liable to be formed in the fuel bed with thin fires, which allows more CO_2 to pass into the gas. There should be three zones in the fuel bed of every gas-producer—namely, ash, fire, and green-coal zones. There are many gas-men working to-day who are entirely ignorant of the necessity for these zones. Such men merely content

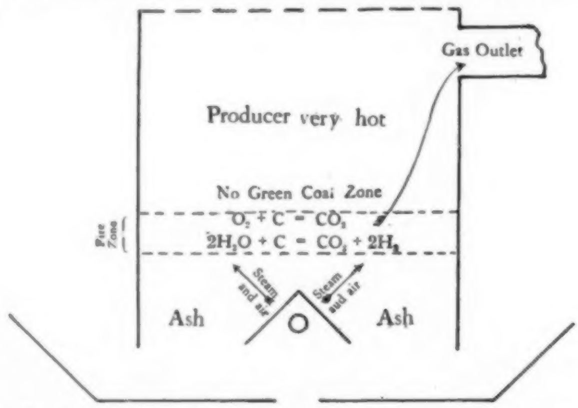


Fig. 1. Showing a fire which is kept too low. The CO_2 formed passes undecomposed into the gas.

themselves with measuring the distance of the fire from the top of the producer, and then add more coal, or otherwise, accordingly.

This is not sufficient, as it gives no idea of the depth of the fire zone, which is most important in the efficient working of the producer. If this zone is too thin it is probably due to too large a quantity of ash.

CONTROLLING THE FIRE.

The proper way to control the state of the fire, and to ensure that each zone is of the proper thickness, is to take a steel rod long enough to reach to the level of the cone. This rod is then forced through the whole mass of the fuel bed until the distance measured off indicates that it has penetrated the required length. It should be allowed to remain in for a few minutes. On withdrawal it will be found that it is divided into four parts: first, a sooty portion, which is that above the fuel bed; then a tarry portion, which shows the green-coal zone; then a red-hot portion, defining the fire zone; and at the end a black-hot portion, showing the depth of ashes above the cone. The green-coal zone should measure from 10 in. to 12 in., and the fire zone about 15 in. These are the two most important points to watch, and at the change of each shift it should be a regular practice to measure these zones, so that the condition of the fires can be noted before taking over. If the green-coal zone is not deep enough the producer will be very hot, and the gas of poor quality.

Gas of a moderate temperature is always the best gas, but many gas-men erroneously think otherwise, even to the extent of melting down the charging bell. A very hot producer can be cooled down by the use of more steam and less air, but a limit can be reached where an excess of steam is very objectionable. It also favours the production of

carbon dioxide, because at low temperatures the reaction $C + 2H_2O = 4H + CO_2$ tends to take place. Also, a large amount of steam may pass through undecomposed. This has a serious corrosive effect on the lining of the furnace, causing port ends to drip and the walls to run.

It will readily be seen, therefore, that great care must be exercised in controlling the various zones of the fuel bed, if the efficiency of the producer is to be maintained.

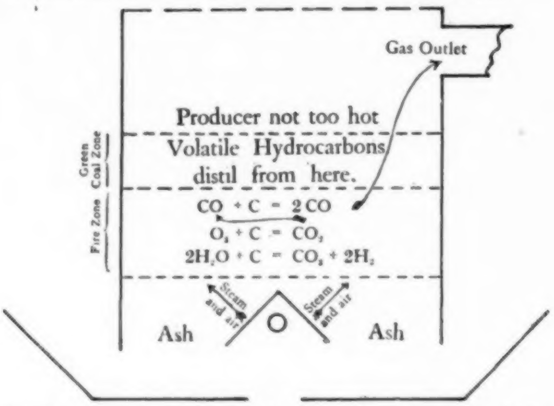


Fig. 2. Diagram showing the three zones in their proper relative proportions. The CO_2 first formed in the lower portion of the fire zone is later decomposed to CO in the high portion.

STEAM AND COAL SUPPLY.

It is good practice to burn about 5 lb. of coal for every pound consumed by steam, and it should be the pleasure and duty of the gas-man to so regulate his steam and air supply that an even temperature is maintained: just sufficient to ensure complete combustion of the steam blown in. A good gas should contain 40% or more of combustible components, of which 24/26% should be carbon monoxide (CO) and 12/14% hydrogen (H).

Only dry steam should be supplied to the producers, as this has a very important bearing on the quality of the gas. All horizontal steam-lines should have a steam trap large enough to drain off all the water formed by condensation. This should be placed near the tube blowers or steam-jet blowers. If no steam trap is fitted, the water in the steam thrown into the air supply quickly lowers the temperature of the gasification zone. The result of this is that water vapour passes over with the gas, and so into the furnace, with the results previously referred to.

A gas-man should know something of the composition of the coal he is using, but I am afraid there are very few foremen even who have any knowledge of this. The composition of the coal is very important, particularly the nature of the ash. If this is deficient in silica and high in oxide of iron, it fuses easily and causes an excessive amount of clinker. Coal of this description should be worked at as low a temperature as possible, and for preference mixed with other coal containing less ash or ash higher in silica.

It is not sufficient, in making analyses of coal, merely to determine the amount of ash contained. The nature also of the ash should be discovered and the gas foreman informed.

AIR AND STEAM CONTROL.

On many producer plants, even at the present time, the air control is very crude, and the importance of any control at all is often entirely overlooked by the gas-men, and sometimes by the foreman himself. I have often seen the air control on steam-jet blowers so little used that they have become fixed and immovable. In this case the same quantity of air always enters the producer regardless of the condition of the fires or the quality of the coal being used. This is quite wrong, and such a practice may easily be the cause of persistent bad gas and consequent loss of production. To get the best results, a turbo-blower should be installed in addition to, and independent of, the steam-jet, and the two should be under separate control. By this arrangement the air entering the producer is not carried in by, and the quantity entering is not dependent on, the amount of steam blown in.

A separate control of air and steam is of great importance in the case of coals containing a high percentage of sulphur. Sulphur is a very objectionable element to have in the gas, as there is a danger of it being absorbed by the charge, especially an acid charge. High sulphur coals (over 1·5%) should be worked with a large amount of steam and a minimum of air.

If the air supply is not under proper control, or overlooked, high sulphur in the steel is the inevitable result, or, at the best, many hours delay, with consequent loss of production. And now the question of poking arises.

If only caking coal is available, a uniformly good gas cannot be maintained without much poking. This means hard work for the gas-man, and his job is hard enough and dirty enough without this; in fact, his job is easily the most undesirable on the plant. Wherever possible, mechanical pokers should be installed, if only from a humanitarian point of view. But, apart from this, there are many advantages to be gained by the use of mechanical pokers, the chief of which are: (1) The rate of gasification is increased. (2) The quality of gas is improved. (3) The amount of manual labour required is reduced.

REDUCING LABOUR COSTS.

The installation will cost a little extra, but will quickly pay for itself by increased production and lower labour cost. Nowadays, men should do the thinking only, and wherever possible machines should do the work. But where hand-poking has, unfortunately, still to be done (and I believe at the present time the number of hand-poked fires is still in excess of the number mechanically poked) the question of poking holes is a very important one. It is quite possible to lose an appreciable amount of gas from this source, if the holes are improperly constructed. Some holes are closed with a stopper, which may or may not prevent the escape of gas. More often than not, small coal or dust prevents it fitting properly in place, with the result that a constant stream of gas fills the atmosphere instead of the furnace. When the stopper is lifted out for poking, the loss of gas is appalling. Another form of stopper is a small cast-iron ball held in a concave pan containing the poker-hole. This is also unsatisfactory, as the poker-hole becomes worn out of round very quickly with constant poking, and the ball does not properly close the aperture, thus allowing a large volume of gas continually to escape. Another contrivance is the water-sealed cover, which is lifted off when poking has to be done. This certainly prevents any escape of gas while the cover is on, but when taken off for poking, while poking is proceeding, and before the cover can be put on again, a large amount of gas escapes. In a normal hand-stoked producer, with five or six poking-holes, with poking going on at least every five minutes, this means a considerable loss of gas on each shift. To avoid this as much as possible should be the aim of every melting-shop manager who wants to keep down his gas bill without lowering his output.

The steam-blown poking-hole is a step in the right direction. In this arrangement a circular steam-pipe surrounds the underside of the poking-hole. When the cover is lifted, minute jets of high-pressure steam blow downwards into the producer. This causes a downward draught which effectively prevents any escape of gas. Up to a point this is perfectly satisfactory, but it has one serious disadvantage. A large amount of steam and air is introduced into the producer, which, mixing with the gas, passes over into the furnace. In my opinion this disadvantage far outweighs any benefits derived from the conservation of the gas.

The device which I have found to be of the most practicable value is a modification of the cast-iron ball arrangement. This consists of a ball about 5 in. in diameter, through the centre of which a hole, ¼ in. larger than the diameter of the poking-rod, is pierced. The hole of the observation casting is made about 2½ in. diameter at the top, and machined to the radius of the ball, as will be seen in the illustration Fig. 3. In use, the ball is placed on its solid side, closing the hole. When poking is to be done or the gas has to be observed, it is turned round so that the hole of the ball connects with the poking-hole. The poking-rod is then inserted in the hole of the ball, through the poking-hole, and so into the producer. The ball accommodates itself to the movements of the poking-rod, sealing the hole all the time. When the rod is withdrawn, the ball is turned over with the point of the rod, without any loss of time or gas.

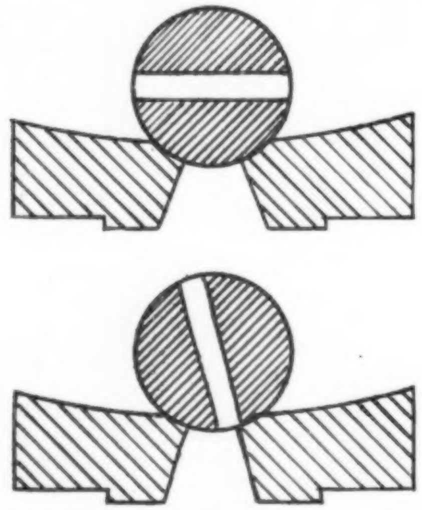


Fig. 3. Poking Device.

The cleaning of the producer is also of great importance. All surplus ash should be removed and clinker knocked down at least every 24 hours. If left any longer, the result will be too much ash and too little gasification zone. If the same man cleans the same fire every day or night, as the case may be, it is always easy to fix the blame on the right party if any trouble arises.

If a fire is kept in proper condition, and worked intelligently, it should be cleaned and the producer making gas again in less than an hour. Mechanical producers of the revolving type are usually much larger than those of the static type, and gasify more coal per hour. They are generally fitted with an automatic ash-removal system which removes the ash at short intervals, but they require "breaking down" to remove clinker at least every 24 hours. Mechanical producers have the advantage over static producers in the matter of labour costs.

Three static producers, each gasifying 15 cwt. of coal per hour, would require the labour of two men, whereas, with mechanical producers of the Wellman or Morgan type, one man would gasify about 8 tons of coal per hour. In addition to this, of course, there would be one mechanic and one electrician in almost constant attendance, to look after the motors and arrangements for slag disposal, but, all told, the labour required in a battery of these producers is less than half of that employed on a battery of the static type of equal producing capacity.

In conclusion, I would like to point out the necessity for more control over the gas supply. Gas should not be carried in flues over a greater distance than 600 ft., nor its flow retarded by many changes of direction; otherwise the loss of pressure is serious. The restriction of flow causes an excessive back pressure on the producers, reducing the gasification capacity.

The gas delivery temperature should be about 1200° F. A higher temperature is not desirable, as it may indicate gas of poor calorific value. At the same time, the latent heat of the gas should not be lost through radiation, and, in the case of overhead carriage, insulating the flues between the shell and the brick lining, saves enough heat to be noticed in the expenditure for fuel. An automatic regulator in the gas system is always a good investment in these days of heavy costs and small profits.

In a battery of five or six furnaces, all drawing gas from one common main, there are always occasions when, owing to one or two tapping, and perhaps another fettling, less gas is required for the time being, but, more often than not, the same amount is still being made. An automatic regulator will control the gas generation in terms of the consumption. This is attained by arranging that regulators connected to the main shall control the pressure of the steam and air supplies to the producer. These regulators are not, of course, required to hold these pressures constant; they are required to vary them in terms of the demand on the gas main.

The Ford Foundry at Cork

(Continued from page 5.)

patterns, and it is thus possible to trace defective castings by the date disc and the man's letter-stamp on them. The handling of sand is reduced to a minimum because the machines are fed from hoppers, which are in turn fed from an overhead sand conveyor.

At the cupolas a close check is kept on coke and metal consumption, and there is a careful comparison of the metal that is charged in the cupola with the amount of metal that is poured into moulds. There are squads of men whose work is only the casting of the metal, and careful calculations are made to obtain data about the cost per ton of metal for pouring and the cost per ton of castings produced. There are two drag conveyors and two pendulum-type conveyors in the Ford foundry. Many operations in the foundry are interesting, apart from actual moulding. The method of blacking cores is to dip them into a tank of black-wash, and the time that is saved by adopting this method can only be appreciated by foundrymen who have experience of orthodox methods. The moulding sand used in the foundry is raised by means of a suction system to an overhead magnetic separator, and it is then reconditioned for re-use in the foundry.

In connection with the core shop there are three large continuous core ovens, and at the time of the visit two new continuous-drying ovens were being erected. The temperature of the core ovens is scientifically controlled, and is taken at six points by resistance thermometers. A twelve-point indicator serves two ovens which are side by side. The temperature at each station can be read by bringing the pointer to the number of the station required. In this way the danger of hot spots in the oven is eliminated. The thermometers used are those of the Cambridge Instrument Company. Every endeavour is made in the foundry to keep the atmosphere clean. For instance, on the shake-out floor, at the end of each conveyor, there is a suction system beneath the floor for taking away the fumes, this being composed of two fans that are operated by a 60-h.p. motor. In the fettling shop also every endeavour is made to reduce the dust nuisance. There are, for instance, 50 tumbling barrels, and a dust-suction system is fitted over each of them.

This concludes what is in effect a very brief description of what is probably one of the finest foundries in Europe, and it is difficult to visualise a casting-producing organisation that can be more efficient or better equipped for the production of high-grade castings to withstand strenuous service conditions.

METALLURGIA

The British Journal of Metals.

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

About Ourselves

THE time is opportune for the publication of a metallurgical review which will be in effect a forum for the discussion of problems of laboratory and workshop. Its editorial function will be to discuss research work and metal production, especially in the light of the new alloys, new blast-furnace practice, open-hearth and heat-treatment methods. There will be articles, by authorities, on welding research and development, spun and centrifugally-produced finished and semi-finished stocks and materials. As there is a natural affinity between basic metal production on the one hand, and the finished mechanism on the other hand, it will be essential to give concern to the handling and machining of castings and forgings, in which, as the weight of metal involved rises, so does the machine-shop risk and concern with metal values. The new alloys have produced a new set of machining conditions, and the machine shop superintendent requires to have accurate knowledge of the chemistry and physics of ferrous and non-ferrous metals and alloys. It has been correctly stated that the new alloys have invaded the province of design. No longer can steel be described satisfactorily or with full accuracy as " mild " steel or " case-hardening " steel ; consideration of whether the open-hearth product is acid or basic, the subsequent product as alloy steel, and a pre-knowledge of the tensile strength, elongation, and the necessary heat-treatment characteristics are of interest to manufacturers who have to translate their materials into gears, crankshafts, and innumerable machinery parts. On the non-ferrous side such alloys as aluminium bronze, with its tensile strength approximating to that of carbon steel has introduced new problems, and, as an inherent property of the metal, " machineability " must be considered as a physical metallurgical characteristic. Then in regard to machine-shop practice, the policy of this journal will be to treat it as a logical extension of the other metallurgical properties of metals because machining properties are now recognised to be definite characteristics with which the metal manufacturer must concern himself. It can be said truthfully that, at the present day, metal users and machine-tool designers, the purchasers of machine tools, and those in charge of metal-component finishing and heat-treatment ought to be informed of the metallurgical content and characteristics of the metal they are using.

FORTHCOMING ARTICLES

"Some Structural Characteristics of High-Chromium Irons and Steels." By J. G. H. MONYPENNY, F.Inst.P. (Messrs. Brown Bayley's Steel Works Ltd., Sheffield.)
"The Welding of Metals. With Special Reference to Flux-coated Electrodes. By EDWARD DACRE LACY.
"The Value of Light Alloys in Engineering." By SAMUEL WHYTE, B.Sc.
"Principles and Uses of Wire Rope." Part II. By W. A. SCOBLE, D.S.
"Alloys in Steel Castings." By F. A. MELMOTH.
"Refractory Materials," Part II. By COLIN PRESSWOOD (Chief of Technical Department, Gerneal Refractories Ltd.)
"The Thermal Conductivity of Metals and Alloys." By J. W. DONALDSON, D.Sc.
"Die-Casting Limitations." By D. RICHARDS.
"Electric Heat-Treatment of Metals." Part II. By W. J. MILLAR, and A. G. ROBIETTE, B.Sc.
"Errors in Steelmaking." Part I. By WALTER LISTER.
"The Choice of Raw Materials in Malleable Cast Iron." Part I. By J. V. MURRAY.
"Notes on Iron and Steel Foundry Practice." By BEN SHAW.
"Notes on the Centrifugal Casting Process." By J. E. HURST.

The publication of the first issue of a journal of this kind may be claimed to be an epochal event in industrial history. Of the making of books there is no end ; this is equally true of new journals, and there is no excuse for the publication of journals that have not a definite policy and that do not meet a need. Many of the foremost metallurgists in this country were consulted before decision was made to publish this journal, and there was a remarkable unanimity of opinion as to its potentialities ; we would take the opportunity now of thanking them for their counsel, and also those firms who have sent us congratulatory letters. The assertion that the launching of such a journal as this is an epochal event does not admit of question ; those who doubt it are invited to consider the influence that certain journals have had on engineering in the past century, and to remember that more progress has been made in connection with blast-furnace practice, the development of non-ferrous alloys, etc., in the past ten or twenty years than in the previous half-century. A determined effort is being made at the present time to revive the iron and steel industry by improving its organisation, the perfecting of processes, and the installation of modern equipment ; this journal will consistently give its support to progressive elements. It will be the hope of its promoters to be regarded as the mouthpiece of the British steel industry, and it will give publicity to whatever, in respect to plant and practice, will aim at increasing its efficiency. There is no reason why the iron and steel industry of this country should be languishing while in other countries it is prosperous. Year by year metallurgical changes come faster, and British industry is not, in regard to science and production, behind that of Germany, France, and the United States. The journal will be non-political, but it will reserve the right to express opinion on questions of economics and organisation.

With regard to the policy of METALLURGIA, it cannot be emphasised too strongly that the editorial and advertising departments will be distinct and separate. Descriptions of new plant will be published without fear or favour. With regard to production, there is no reason why a high-grade technical journal should not reach the standard of a really beautiful production. Not only will it prove to be a forum for the discussion of metallurgical questions, but it will form a bridge between laboratory and workshop. In this first issue—and in subsequent issues—there will be many omissions, but the policy and even the format of a journal are shaped largely by its readers. Because of this we solicit the expression of views in the form of letters or more lengthy contributions. Further, the fact that the views of a correspondent may not be our views will not debar him from stating his case. We make our bow to the metal manufacturing and metal-using industries in full confidence of their support. It is phenomenal that, before publication, a large number of subscribers have been enrolled, and although the majority of these are British, some have come from America and the Continent. Finally, we want constructive criticism—even destructive criticism has a value. In twelve months' time the journal may differ in important respects from this first number, and new features will doubtless have to be introduced, but on one point our readers can be assured that a high level of production will be maintained. METALLURGIA will endeavour to be worthy of the great industries it represents.

The Scope of Metallurgy

Nowadays, while a metallurgist is a metal-worker, a metal-worker is not necessarily a metallurgist: invariably some other term is applied, indicating the particular kind of metal work with which he is associated. Primarily, metallurgy is the art of extracting metals from their ores, refining them and adapting them for use in manufactures, and the work of the metallurgist was formerly confined between certain well-defined limits, commencing where mining finished and ending where the manufacturer made use of the crude pig or ingot of metal supplied. For many years now the sphere of the metallurgist has been gradually increasing, and it is only due to his influence on the industrial uses of metals that such remarkable progress has been made.

The metallurgist is essentially a chemist, but the physical properties of a metal are equally as important as its chemical composition, and to extract metals profitably intricate mechanical devices are essential. Something more than a knowledge of chemistry is necessary—some knowledge of physics, for instance—and he should be familiar with mechanical principles. The reduction of ores involves heat, and the nature and properties of fuel must be given consideration, and since metallurgical operations are usually conducted at high temperatures, not only must the design of furnaces be given careful thought, but the character and composition of the material composing the furnace, more especially that part with which the metal comes into contact, must be capable of withstanding the high temperature without interfering with the quality of metal produced.

While the extraction of metals from their ores may rightly be termed an art, the relation of metallurgy to industry is more nearly a science. The application of this science to all forms of engineering is largely responsible for the rapid developments made during recent years. The infinite possibilities in metal combinations is creating an Alloy Age. The production of corrosion-resisting irons and steels, high-tensile light alloys, high-test irons, die-casting metals, alloy welding rods, a wide range of alloy tool steels to give almost any desired property, and also special high-speed cutting alloys indicate the trend of development. Metals that formerly were used very little are being profitably employed in these metal combinations, tungsten, chromium, nickel, cobalt, vanadium, and manganese being a few of the metals alloyed with iron and steel to produce such physical qualities as hardness, resistance to wear, or to corrosion, high tensile strength or heat resistance. In a similar manner, particular properties are being secured for the light alloys by introducing nickel, manganese, silicon, etc. Not only has progress been made in the development of alloys to resist corrosion, but protection to other metals and alloys that are subject to corrosion from various causes can now be effected by the application of a coating of some other metal that is a resistant of corroding influences. Electro-plating, tinning, and galvanising are some of the best-known methods; some of the metals used for this purpose include lead, tin, zinc, copper, cadmium, chromium, and aluminium. Developments in electro-deposition have made considerable progress, and in addition to dipping the article to be treated into a bath of molten metal, much progress has been made in spraying a protective metallic coating on work and subsequently submitting it to a high temperature. The value of heat-treatment on various alloys cannot be over-estimated.

Developments in the production of alloys of a more complex character than formerly, and capable of resisting physical forces to a greater extent than was previously considered possible have had a considerable influence on all sections of the foundry. It can be truly said that the progress of engineering depends upon the production of more reliable materials, and new materials to meet conditions that exhaust the usefulness of existing materials, and it is only by persistent research that the metallurgist can meet the demands of progress.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

Nov. 29. Extra General Meeting. Open debate on "The Registration of Reliable Tests of Power-plant Machinery," to be introduced by R. H. Parsons (Member).

Dec. 13. General Meeting. "Bearings for Power Shafting," by Professor G. F. Charnock (Member of Council).

INSTITUTE OF METALS.

Nov. 26. "The Modern Development of the Steam Locomotive," by G. W. Wooliscroft, D.B.E., Wh.Sc. Birmingham Section.

Dec. 4. "Coke Carbonisation and By-Products," by G. Crift. Swansea Section.

Dec. 9. "Melting Furnaces," by G. L. Cassidy. Scottish Section.

Dec. 10. "Nickel in Non-Ferrous Foundry Alloys," by W. T. Griffiths, M.Sc., F.I.C. North-Eastern Section.

Dec. 12. Joint Meeting with the Institute of British Foundrymen. D. F. Campbell, M.A., A.R.S.M., and W. S. Gifford will give a paper on "Melting Metal by Electricity." London Section.

Dec. 12. "Die-Casting," by A. H. Mundey. Birmingham Section.

Dec. 13. "Physical Testing," by Professor F. C. Lea, D.Sc. Sheffield Section.

INSTITUTE OF MARINE ENGINEERS.

Nov. 26. "The Origin and Development of Heavy-oil Engines," by A. F. Evans. Akroyd Award Prize Paper.

INSTITUTE OF BRITISH FOUNDRYMEN.

Nov. 21. "Steel Castings," by C. Howell Cain, of Braintree. London Branch.

Nov. 22. "The Mechanical Handling of Foundry Materials," by R. Spriggs, of Loughborough. Birmingham Branch.

Nov. 22. "The Metallurgy and Production of Modern Grey Iron Castings," by A. E. Macrae Smith, of Dartford. Sheffield Branch.

Nov. 23. "Work in Jobbing Foundry—Pipes, Rope Pulleys, and Hydraulic Cylinders," by A. Sutcliffe, of Bolton. East Midlands Branch.

Nov. 23. "Hidden Facts in Oil Sand Practice," by F. Hudson, of Birmingham. Newcastle-on-Tyne Branch.

Nov. 30. "Continuous Casting Methods," by A. S. Beech, of London. At Bristol; Wales and Monmouth Branch.

Dec. 7. "Nickel in the Iron Foundry," by A. B. Everest, B.Sc., Ph.D., London. Lancashire Branch.

Dec. 7. Address by the President of the Institute, Wesley Lambert, Esq., during the afternoon preceding the Annual Dinner. Scottish Branch.

Dec. 7. "The Future of the Foundries in Great Britain, with Special Reference to Continuous Casting," by A. S. Beech, of London. Yorkshire Branch.

Dec. 10. "Machinery and Materials Used in Making Textile Castings," by J. Bell, of Burnley. Burnley Branch.

Dec. 13. "Modern Steel Castings," by F. J. Hemmings, of Wednesbury. Birmingham Branch.

Dec. 13. "Some Notes on the Behaviour of Dissolved Gases in Cast Iron," by J. E. Hurst, of Sheffield. Middlesbrough Branch.

Dec. 13. "Coal Dust and Facings in the Foundry—Some Practical Experiments," by H. Winterton, of Milngavie. Sheffield Branch.

Dec. 14. "Production of Castings for Internal Combustion Engines," by A. L. Key, of Manchester. East Midlands Branch.

Dec. 14. "The Future of the Foundries in Great Britain, with Special Reference to Continuous Casting," by A. S. Beech, of London. Newcastle-on-Tyne Branch.

Dec. 14. "Heat-resisting Cast Iron," by H. Cowan, B.Sc., of Falkirk, at the Falkirk Branch.

Dec. 14. "Steel Making," by Professor C. A. Edwards, B.Sc. At Newport; Wales and Monmouth Branch.

Tungsten Carbide Tools as an Aid to Production

Development Long Overdue. Greater Rigidity and More Power Necessary to get Best Results. Future Machine Designs Involved.

By a Machine-Tool Designer.

MUCH has been written—much has been said—regarding the merits and demerits of the tungsten carbide tools as at present available. It is not proposed in this article to discuss the chemical formation of these alloys, but merely to look at what we have available at the present time as an aid to production. In considering this alloy a new technique is required. It must not be confused with high-speed steel—it is a totally different proposition. If it is considered as a cheap form of diamond, one realises that it is a valuable product and must be treated with special consideration.

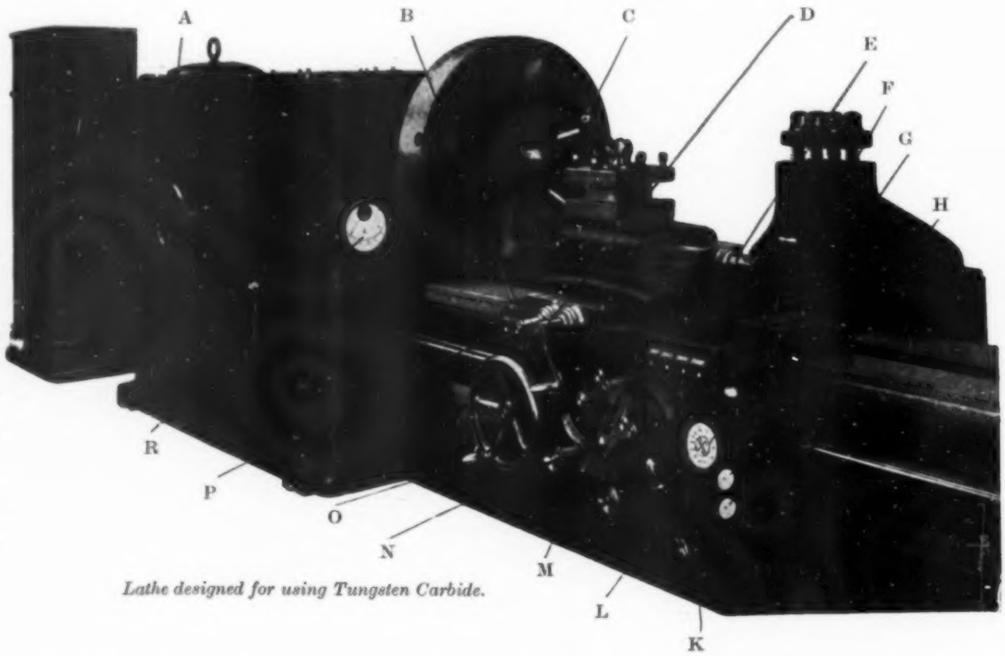
One frequently hears the statement made that the material is so brittle that its use is limited, and because of this fact it will quickly pass from favour. Let us make no mistake, this development is now long overdue. In the old days of the carbon-steel tool we carried on. High-speed steel was produced, not by any means perfect at first, but still a step onward. This high-speed steel has been constantly improved, but no further change of importance had taken place until the advent of this alloy. Therefore it is safe to assume that if we have not got a perfect product to-day, it will come in the future, possibly in the very near future, and it behoves us to consider very carefully the planning of new plant which we contemplate purchasing, with this fact in view.

As an aid to production it is essential that we use this alloy on suitable machines. Little success, if any, will be obtained by the man who gets a sample tool, takes it out to the turner on the average lathe, and instructs him to "try this out and see if it is any better than that you are using."

Machines that have been found most suitable for using this alloy, so far, have been high-class high-speed lathes, vertical boring mills (of robust construction), facing heads in horizontal boring machines, and inserted bit cutters on high-power milling machines. Success has also been obtained in tipping drills for drilling hard materials. Automatic turning machines offer scope for the use of this alloy, and many successful jobs have been tooled up on these machines. When laying out work with a view to using this alloy it must be borne in mind that it has several features which are unique, causing a revolution in machine-tool design—

1. The fact that it will remove metal at a much higher speed than the best high-speed steels.

A—Altering main spindle speeds.
B—Surfacing movements front slide rest.
C—Locking tool post.
D—Surfacing movements back slide rest.
E—Longitudinal movement to slide rest.
F—Engaging and disengaging feeds.
G—Indicator showing main spindle revolutions.
H—Altering feeds.
K—Push buttons controlling main motor.
L—Direction of feeds.
M—Engaging surfacing or longitudinal feeds.
N—Engaging feeds or high speeds.
O—Hand-wheel moving saddle.
P—Push buttons controlling auxiliary motor for high-speed movements
R—Amperemeter.



Lathe designed for using Tungsten Carbide.

2. That by using a suitable combination of speeds and feeds a very high finish can be obtained.

3. That it does not heat the work operated upon to anything like the same degree that high-speed steel does. In fact, heavy cuts may be removed, leaving the work practically cold.

These advantages are to a certain extent offset by—

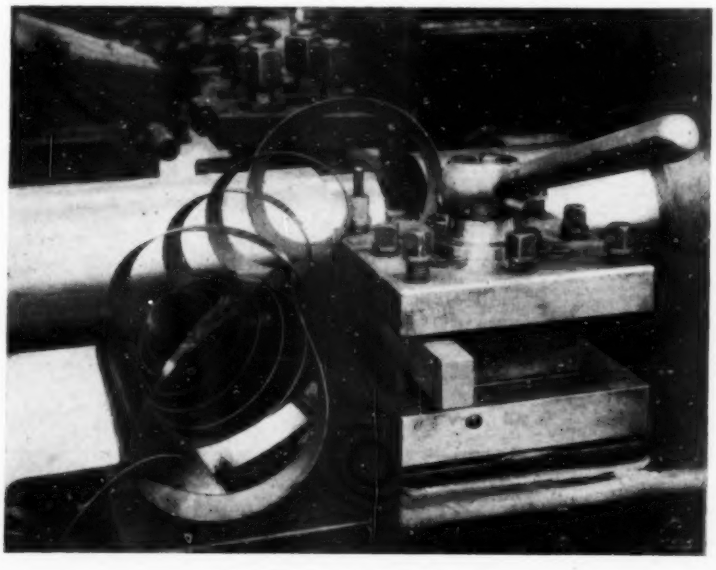
1. The liability of the tool to chip if not properly used.

2. The difficulty in grinding the tool to the required shape.

Let us consider the question of using this alloy on the engine lathe. The first essential detail to ensure success is rigidity. By this we mean not only the rigidity of the saddle, but also that of the tool support. The tool must be held rigidly, with as little overhang as possible. If overhang is essential, some support must be arranged under

the nose of the tool. To give an example: A parting-off tool was made $\frac{3}{8}$ in. wide, mounted on a steel shank 3 in. deep. This was used to part off the header from cast-iron rolls, 14 in. diameter. The first two or three attempts met with utter failure; although there was no apparent vibration, the tool chipped and gave trouble. The matter was carefully considered, and a wedge was made to support the tool right at the point, reaching down to the slide of the machine. No further trouble was experienced. A feed of $\frac{1}{32}$ in. per revolution was used, and a surface speed when starting of 500 ft. per min. The cut was allowed to travel in half-way. The feed was then stopped, and the speed increased again to 500 ft. per min., and the remainder of the header was parted off, the operation taking less than one-quarter of the time previously occupied.

Second to rigidity comes the power available. To give some idea of the difference in power required, as against high-speed steel, test cuts were run on the same material, and under exactly the same conditions, on a lathe specially constructed for the use of tungsten alloy tools. The machine Fig. 1 was fitted with an ammeter on the head-stock and a revolution indicator on the saddle, so that the information obtained could be relied on as being accurate.



TUNGSTEN CARBIDE TOOL

Cutting 30 tons tensile steel, 350 feet per minute. Depth of cut $\frac{1}{2}$". Feed $\frac{1}{16}$"

The test cuts were taken on a bar 7 in. diameter. The machine required 30 amps. to run it at a speed of 150 to 200 r.p.m., and 16 amps at 50 to 100 r.p.m. The results obtained are as follows:—

(*a*) TUNGSTEN CARBIDE TOOL.

Depth of Cut. In.	Feed. In.	R.p.m.	Amps.	H.p.
$\frac{1}{2}$	$\frac{1}{16}$	150	200	50
$\frac{1}{8}$	$\frac{1}{32}$	200	65	16
$\frac{1}{32}$	$\frac{1}{64}$	200	35	9

(*b*) 18% HIGH-SPEED TOOL.

Depth of Cut. In.	Feed. In.	R.p.m.	Amps.	H.p.
$\frac{1}{2}$	$\frac{1}{16}$	30	60	15
$\frac{1}{8}$	$\frac{1}{32}$	50	40	10
$\frac{1}{32}$	$\frac{1}{64}$	100	36	9

After carrying out these tests, another run was made with the object of obtaining a high finish on certain work, excellent results being obtained by a cut $\frac{1}{32}$ in. deep, $\frac{1}{64}$ in. feed, at 400 r.p.m., the power absorbed being about 15 h.p. From the above figures it will be realised that drastic alteration to the average engine lathe would be required to use successfully tungsten carbide alloy tools to their utmost advantage. From experience it is safe to say that usually the feed-box gives out first, then the saddle aprons, and finally the headstock driving gear.

Another point in adapting engine lathes for this purpose is the question of the tailstock. It is essential that a live centre be used in the movable headstock, or trouble is quickly experienced. There are various designs of live centres on the market, some of which are admirably adapted to the ordinary machines for lighter classes of work, but it is advisable on heavy tools to redesign entirely the barrel of the loose headstock, and equip the centre with roller bearings and suitable ball-end thrust, keeping the bearings as large as possible, and the distance between the front and back roller bearing as long as possible.

The above remarks on the adaption of lathes apply largely also to vertical boring mills. These machines generally appear to be of more robust construction, and certainly stand up better in practice. Mostly, the trouble experienced with these machines has been with the drive from the motor to the gear-box, this in many cases being too light.

On auto lathes tungsten carbide tools may be used for two purposes—

1. To enable the machine to be run at a higher speed, and so increase output.
2. To obtain longer runs between grinding, especially where one tool in a layout is in the habit of giving trouble.

In all cases the tool should be chosen for the work for which it is intended, with care. Choose a tool with as large a shank as possible, but with a tip which is in proportion to the size of the cut to be taken. In practice it has been found that where a tool with, say, 1 in. tip on it is used for $\frac{1}{4}$ in. reduction, the tip is more liable to chip than if a smaller tip was used. This apparently is due to local heating, which with a smaller tip is more easily dispersed.

To obtain successful results from tungsten carbide tools the grinding requires careful consideration. This material cannot be ground on the ordinary shop tool-grinding wheels, the alloy being practically as hard as the diamond. A silicon carbide wheel is required. There are a number of these on the market, notably "Norton" Crystolon or "Carborundum" wheels and Naxos-Union N.U. wheels. Generally speaking, a soft wheel is required; grit 40 to 60 is recommended for rough grinding, whilst a finer wheel, 90 to 100 grit, is recommended for finishing. In all cases finish-grinding is recommended to be done by hand, using as light a pressure on the wheel as is required to make it cut. This material may be ground without water, there being no fear of drawing the temper; but in some cases, for the benefit of the wheel, water is found to be advisable. This is a matter of experience, but it is certain that if water is used a copious supply must be employed, not a mere trickle. If it is desired to use these tools for producing a high finish, such as finishing reamers, etc., the edge should be stoned to a very high finish. Indeed, for all classes of work, the higher the finish produced on the tool the better the results. If the tool is left with marks on it from rough grinding, it will be found that fractures will tend to develop from these points.

It is usual to purchase these tools ready made up—that is to say, with the tip welded on a suitable shank. If it is desired to make special tools, the alloy may be purchased in suitable size pieces and welded by the user, but considerable care and experience are required to make a satisfactory job. Copper is recommended as a brazing material, and it

is essential that the tool shank should be milled or ground so that the tip is a perfect fit on the seat to which it has to be welded.

A few interesting examples of the use of this alloy as an aid to production are: In machining a Diesel engine-cylinder liner, 14 in. bore, 28 in. long, in cast iron, difficulty was experienced in getting a finishing tool which would stand up and give a truly parallel hole. A cutter-head was made, using tungsten carbide alloy tipped tools, which entirely overcame the difficulty. The speed was not materially increased in this instance, but the results and finish, from the point of view of accuracy, were all that could be desired.

Trouble was experienced in milling the flat faces of cast brasses. The average life between grinds of a cutter was between two and three hours, production being six to eight half brasses per hour. A head was made, using four ½-in.-square tools, with a small tungsten carbide alloy tip. The output was doubled, and the time between grinds was increased to four or five days. The cutter was run at a surface feed of 200 ft. per min.

Ball-bearing housing covers were being machined on auto lathes at the rate of 6½ mins. each.

Extra production was required, and the machine was re-tooled, using alloy tools. The time was cut to 3 mins. each, and a batch of two gross was machined without any attention to the tools whatever.

CUTTING MATERIALS.

A Note on Developments in Practice.

The problem of determining the most suitable cutting material for metals and alloys has always been a difficult one, and any attempt to dogmatise in regard to the kind which gives the best results in every circumstance and under all conditions results in much controversy. Since the days of the ordinary carbon steel the subject has been a very controversial one. The advent of new or improved cutting materials has generally been received with reserve. This conservative spirit in engineering factories, and machine shops in particular, is largely due to the fact that new cutting mediums usually require new conditions, and the adjustment of machines or organisation to give the most suitable conditions may be too involved and costly to make the use of the new cutting material worth while. Furthermore, operators of machines, whether skilled or unskilled, become thoroughly conversant with a particular cutting material as their experience with it increases, and any general change made frequently results in reduced output and much wastage until sufficient experience has been gained to remedy defects in its use. Prejudice often operates against the successful use of a new cutting material, not only by the machinist who is using the material, but by the foreman also.

Increased speed of production is not always welcomed, and difficulties sometimes arise which could very soon be overcome if the will to get full value from a new cutting material predominated. The discovery of self-hardening steel by Mushet was a considerable advance on the ordinary carbon steel. He discovered that by adding tungsten to a tool-steel better results were obtained by ordinary cooling than by quenching, that it was, in fact, harder; and tool steels containing tungsten of a composition recommended by him were much superior in cutting power to ordinary carbon steels. The original Mushet steel contained 2% carbon, 5% tungsten, 0.5% chromium, 2·5% manganese, and 1·3% silicon. To get the best result from the self-hardening steel greater speed was required, but progress with it was slow; indeed, it was not until the improved form of tungsten steel was developed that a movement towards higher speeds received an impetus. The improvements made were largely as a result of heat-treatment, which enabled the steel to retain its hardness even after heating up to a dull red. Due to the increased cutting power at speeds previously considered to be impossible, these steels became known as high-speed steels.

The effect of high-speed steel was a revelation, and machine makers gradually adjusted their machines to the new conditions necessitated by faster and heavier cutting. Many years elapsed, however, before full advantage could be taken of the benefits of this cutting material. But no sooner were machine shops adjusted to make use of high-speed steel when further developments in cutting materials produced the tungsten, chromium, and cobalt compositions, which made almost as much stir in machine-shop circles as had been made by high-speed steel. Several of these are in use for a wide diversity of operations, and are recognised by various trade names. These alloys are harder than high-speed steel and presented difficulties owing to their brittleness. It has long been known that an alloy of tungsten and cobalt is extremely hard, but it is also very brittle, and experiments have been in progress to increase the toughness without interfering with the cutting quality. Tipping tools with the special cutting product gradually became a general practice, primarily to give that degree of support to the cutting edge comparable with a high-speed tool, but also because of economic considerations, the cost of these specially cast products being considerably greater than high-speed steel. Gradually the more efficient machine shops, particularly the shops dealing with repetition work, have been organised and equipped with more modern machines to make profitable use of these harder cutting materials. But, as a rule, developments in cutting materials to cope with the developments that have been made in metals and alloys have been in advance of the developments in machines. Increased cutting power, whether by heavier cuts than has been customary, or by increasing the cutting speed, involves new machines designed to bear the greater stresses imposed upon them.

Few machine designers anticipate the trend of modern developments, and developments in practice are frequently slow owing to the incapacity of machines to give maximum efficiency from new cutting materials. At present another transition period is in evidence as a result of the advent of the sintered tungsten-cobalt products. These are apparently more effective for a wide variety of cutting purposes than any of the foregoing cutting materials. These differ from the cast products in the manner of manufacture. They are not true alloys, but consist of elements in powder form which are sintered at a high temperature and, subsequently, compressed under high pressure, producing an amorphous structure. These sintered hard materials, forming carbide of tungsten, can only be treated with a diamond cone. They have a still greater resistance to wear than the tungsten-chromium-cobalt alloys and do not loose their hardness at all, within the practical range of work for which they are used as a cutting medium. Tungsten carbide of this character is brittle, and requires ample support and a rigid machine to render it effective. Suitable tools having tungsten-carbide bits soldered on are preferably used on very hard materials, for cutting very hard scaly layers, and for thread cutting on very hard materials that resist the best high-speed steels.

The fact that the majority of machines now operating in machine shops cannot be speeded up and yet maintain rigidity in operation, is retarding the full utilisation of the super-hard cutting materials. But want of experience in the use and in understanding the new conditions involved, together with a certain amount of prejudice are other factors that operate against rapid developments in practice with new cutting materials. At present tungsten-carbide materials are being brought into operation to overcome machining difficulties presented by very hard materials, to limit the time in grinding, and, where the machine will allow, to increase production. To get results that compensate for the increased cost, the machine designer will need to either modify existing designs or design new machines to provide greater rigidity at cutting speeds which give the maximum efficiency from their use.

Refractory Materials

PART I.

Their Importance in Metallurgy and the General Principles Governing their Selection and Use.

By COLIN PRESSWOOD, Chief of Technical Department, General Refractories, Ltd.

A WISE, and consequently successful, business man has recently stated that there are two ways (at least) of increasing profits. The first, perhaps the more widely appreciated but difficult one, is increasing sales and production. The second is not so well known, but is neither so difficult nor so dangerous a proceeding. It comprises a thorough search into production costs, the elimination of wasted effort, time and money, and ends often in increased sales on present production. In many plants this implies complete reorganisation, and may mean further capital outlay, but it is safe to say that in most businesses great economies can be made by considering what are apparently unimportant items in production costs.

SERIOUS ITEM IN PRODUCTION COSTS.

It is some such consideration as the foregoing which is responsible in part for the careful attention now given to refractory materials in the metallurgical industries. Those who have studied this aspect of their particular process find themselves repaid, and realise that the production of heat-resisting materials is almost a " key " industry upon which their own depends for its success. It is reasonable to suggest that the growth of metallurgical industries in some districts is due in part to an abundant supply of heat-resisting materials.

Furnace linings were originally discovered more or less by accident, the case of crucible steel furnaces being of interest. It is said that Huntsman, seeking a lining for his new furnaces in Sheffield, found road sweepings successful, and as demand increased beyond supply, there arose a business in manufactured " road-sweepings." The local roads were made of the hardest local rock, called " Ganister " (a name still applied to road metal of various kinds), and were often bonded with fire-clay. The Ganister owes its hardness to its composition of quartz grains surrounded by a siliceous cement. Little wonder then that it became ultimately the basis of the well-known Sheffield ground ganister and, later, of silica bricks!

The development of furnace linings was for years empirical, whence arose the strong prejudice in favour of materials from particular districts. These remain to-day, and are in many cases explained and supported by scientific investigation of the subject, which began in earnest just prior to the world war. (The study of ceramics, of which this is an off-shoot, was well advanced.) At that time Continental manufacturers possessed knowledge far in advance of that applied to the industry here, but since then there has been much wide and careful investigation of the ample resources of refractory materials in this country. The results are encouraging, research has been justified, and it is clear that the work must be more widely supported by makers and users of these materials. The work of the British Refractories Research Association, centred at Stoke-on-Trent, is supported by the Department of Scientific and Industrial Research as well as by voluntary contributions.

The high cost of refractory materials in ferrous metallurgy is shown by the following figures, due to M. C. Booze, of the Mellon Institute of Industrial Research at Pittsburgh.*

Blast Furnace Stoves and Connections.—Two 9 in. fireclay bricks per ton of pig iron produced.

Open Hearth Furnaces.—Five 9 in. silica bricks, two 9 in. fireclay bricks, 4 lb. of magnesite refractories, and 1 lb. of chrome refractories, per ton of steel.

The same author shows that in the U.S.A. open-hearth furnaces account for 34%, boiler furnaces for 19·6%, and blast furnaces for 6·3%, of the total consumption of refractory materials. Estimates of the cost of refractories per ton of metal produced vary widely, and are rarely known accurately. Nor are figures always published, but it must be considerable. In many steel works this aspect of the processes receives close attention, with the result that costs are reduced, but in most the inquiry is not made, or at any rate is carried out superficially. As an example, a comparatively trivial point may be quoted—that of ingot tiles and ladle-rod covers,—which are said to represent in one works a cost of 1d. per ton of O.H. steel. On a weekly production of 3,000 tons, this means a yearly cost of £625, and investigation of this item was instituted, as there seemed to be good prospect of at least 50% reduction.

UNEQUAL TO THE DEMANDS.

Attention to this aspect of furnace linings, etc., is well worth while, but it is from another direction that extensive interest in the subject has been urged more strongly. Metallurgical, and, in fact, most other high-temperature processes, are being continually modified, and nearly always in such a way as to place greater demands on refractories.

Existing materials have serious limitations, and new ones must be explored, but nature's supplies are narrowed to a few common types, the rarer types being expensive, and their establishment in common use necessarily tedious. Thus, the importance of improving existing types is increased, and, clearly, can only be done by scientific methods. Equally important is the inquiry into the methods and conditions under which the materials are used, and thereby improvements can be made also. The modern boiler furnace serves as an illustration, especially in the application of pulverised fuel. In the early days of this method of firing, the coal was somewhat coarsely ground, and high air velocities were therefore necessary to carry it to the burner, where a veritable blast of coarse coal and ash particles was directed on to the firebrick wall. The method made possible the use of coals of high ash content. Small wonder then the firebrick linings failed quickly and often! Large combustion chambers were built so as to remove the walls to some distance from the flame—a costly and not over successful method. It is safe to say that whilst firebricks have been improved, most of the success now achieved by this method of firing is directly due to modified conditions, such as finer grinding of fuel, with attendant lower blast pressure and velocity, lower ash content where necessary and possible, and finally to water-cooled walls. New refractories have done well in trials, and may serve so well that such modified practice may not always be necessary, as it may well be more costly than a new type of lining whose first cost is above that of ordinary firebricks.

Scientific knowledge has doubtless led to improved quality and to more careful use, but is as yet in its infancy as applied in this direction. It is to be urged upon makers and users alike, but both must remember that this is not by any means an exact science—that is, one whose laws are well established and found generally to apply. There

*Vide " Refractories Journal " November, 1926, page 253.

still remains a good deal of empiricism, many features are not understood, and what appear to be fundamental principles are far more liable to be contradicted than those on which many other industrial sciences are based.

A too-rigid adherence to scientific principles will prove fatal in manufacturing and using refractory materials. This is unfortunate, since it limits specifications which are just beginning to emerge from a mass of data on the subject. They are to be encouraged, but accepted cautiously. The reason for this lies in the fact that the natural minerals used are rarely pure substances. Fireclays are notoriously complex and of widely varying composition, and their true nature is not completely understood. In the case of silica bricks, which comprise essentially silica and lime, the study has been simplified, and knowledge is therefore more exact.

From the careful study of fireclays there has arisen the conception of the alumino-silica group of minerals, and as some of these, known to occur in fireclays, have either been synthesised (*e.g.*, mullite) or found in naturally pure deposits, there has developed the manufacture of such bricks as sillimanite and mullite, which may be more easily investigated.

FIRST COST AND TRUE COST.

The selection and use of refractory materials must be made in the light of—

(*a*) Cost.
(*b*) Their chemical and physical properties.
(*c*) The conditions under which they are to be used.

It must be remembered that true cost is not first cost, for it is measured per unit of finished product in any operation. In blast furnace work, " per ton of pig-iron "; in foundries, " per ton of good castings." The difference is important, but often neglected. The true cost of refractory materials in any operation includes first cost plus labour, plus loss of output during repairs. If a set of furnaces need re-lining frequently, more furnaces may be required for a given output than would be the case if linings lasted well. With frequent renewals, " standby " furnaces are necessary.

Another item is that of fuel consumption, which may be seriously affected by failure of refractories. The cupola is a case in point, for a lining of bricks or other material which melts rapidly will increase coke consumption, extra fluxes may be needed to clear the slag, more slag is produced, and more metal lost therein. A case illustrating the relation of true cost to first cost is that of a forge furnace working at high temperature. The molten scale produced was found to attack rapidly all types of fireclay bricks, whether cheap or high-priced. This was to be expected. Under the specially severe conditions imposed by one job, fireclay bricks in the bottom of the furnace were destroyed in twenty-four working hours and had to be renewed. Special slag-resisting chrome bricks whose first cost was six or seven times that of average fireclay bricks lasted three months. The change was obviously worth while, the " life " being increased fifty times. The life increase, however, need not be strictly proportional to, or greater than, the increase in first cost. The use of more expensive bricks would probably have been justified in this case had they given four times the life, there being a saving in labour and time, and probably an improvement in the condition of the metal. In some cases the cost of labour and loss of production may be so high that a lining six times as expensive might be justified if it lasted twice as long.

In all cases it is the contribution of refractories to unit cost of the product that is to be considered. A producer of non-ferrous metal by the crucible process finds that refractories account for 2s. 9d. per ton, and the metal is worth over £60 per ton. He will be interested in new materials, which will lower that cost. It is claimed that the same metal can be melted electrically with a refractories cost item of 9d. per ton, in which there is far less inducement to try out new materials with a view to cost reduction.

PROPERTIES OF REFRACTORY MATERIALS IN GENERAL.

These may be summarised as follows :—

Chemical analysis.
Refractoriness or resistance to softening under heat.
Expansion with temperature, both permanent and reversible.
Porosity and density.
Crushing strength, both cold and hot.
Conductivity for heat and for electricity.
Abrasion resistance.

In use the materials may have to resist—

Chemical action of slags, dust, gases, metal.
High temperature.
Rapidly changing temperature.
Electricity.

—and the relation of these conditions to the properties outlined above is briefly as follows :—

Refractory materials are complex mixtures of oxides, which can be classified as acid, neutral, or basic in the chemical sense. Slags can be similarly classified, and for the sake of simplicity it is usual to consider acid refractories as best suited to resist acid slags, and so on.

The temperature in a furnace may be considered in relation to the softening point of the lining, whilst it also affects the expansion or contraction and the flow of heat through the brickwork. Rapidly changing temperatures are to be considered along with the expansion characteristics of the material. Slag action can definitely be connected to the porosity, the chemical properties, and the mechanical strength of the material. In most electric furnaces it is necessary that the lining shall not be a conductor whilst in a few the conductivity of the lining is used to advantage.

Laboratory Examination.—This is subjected to the great limitation that it is impossible to adopt the conditions obtaining in works practice. Two important factors are time and bulk, and effects due to these may escape notice in small-scale tests, but quickly show themselves in the works. It has been definitely shown, however, that a useful part is played by laboratory work, and that conclusions based upon it are borne out by works experience. This is shown by the measure of success which has met the Gas Engineers' specification. Laboratory practice has, moreover, been extended recently to include the use of small-scale furnaces, from which still more valuable results are obtained. Technical men prefer, however, to make small-scale trials in actual works conditions whenever this is possible, and on these they draw final conclusions.

The user considering new supplies would do well to examine full laboratory reports, compare these with those on materials on which he has experience in practice, and then, if satisfied, arrange in the first place a small-scale trial. If of bricks, 100 to 500 would suffice. In smaller measure perhaps, this, like laboratory work, has limited use. For instance, a trial batch of bricks on a Siemens furnace roof may fail under conditions which a complete roof could have resisted successfully, the reason being that it may be impossible to accommodate the expansions of the two classes of bricks together.

The foregoing remarks are by no means intended to mean that tests are useless in appraising refractory materials, but merely to act as a warning against their being accepted too rigidly in the present state of knowledge. In the manufacture or the use of such materials there may be as many as twenty factors contributing to success.

To meet a specific set of conditions, it is possible to prescribe a number of characteristics of the refractory. As will be seen later, however, some of these requirements may be mutually exclusive. Compromise is necessary, and herein is scope for intelligent judgment on the part of the purchaser.

Acid-Resisting Steels

By Dr. W. H. Hatfield

Brown-Firth Research Laboratories, Sheffield

THE advances in ferrous metallurgy in this particular field have indeed outrun the most optimistic anticipations of twenty years ago. The corrosion-resisting characteristics of the early crude ferro-chromiums, and of alloys made by melting such ferro-chromium in different proportions with iron, mark the beginning of the development, but such alloys awakened little industrial interest, owing, in the first place, to their indifferent mechanical properties, and, in the second place, to the incomplete and indifferent examination of their resistance to chemical attack.

The problem of rendering iron resistant, or, to the use the better word, "passive," has been studied for a very long time, and it is frequently overlooked that so long ago as 1790, J. Keir* recorded that his experimental work had shown that iron could be rendered passive to certain reagents by treatment with nitric acid; and that Michael Faraday,† so long ago as 1836, had given an explanation of the theory of passivity, which practically holds the field to-day. Ulick Evans‡ has confirmed by direct experiment and demonstration that ordinary iron is rendered passive through the production of a protective film. The influence of chromium in what we now know to be the facilitating of the automatic production of a protective film in ferrous materials was first clearly brought out in the excellent work of Monnartz.§ As regards the industrial development, it may be said with truth that this was left for a decade in the hands of the Krupp Research Laboratory in Germany and the Brown-Firth Research Laboratories in this country, and the industrial world will always be indebted to the excellent pioneer work of Dr. Strauss and Mr. H. Brearley. The former was responsible for initiating the industrial application mainly from the point of view of the chromium-nickel steels, whilst, as is well known, Mr. Brearley approached the matter from the standpoint of hardened and tempered chromium steels.

Since those early days, much development has taken place, particularly in this country through the researches carried out in the interests of Messrs. Thos. Firth and Sons, and it is always of interest to endeavour to review the progress which has been accomplished in such a productive field.

The acid-resisting steels now available industrially are either chromium steels, chromium-nickel steels, or chromium-nickel steels to which other elements have been added. The author proposes, in this short article, to devote his attention to a comparison of the resistance of ordinary mild steel, 14% chromium steel and some chromium-nickel steels of variable chromium and nickel contents. A consideration of the more complex, though extremely interesting, alloys must be reserved for a future occasion.

The analyses of the actual steels which are now to be considered will be found in Table I.

In Tables II., III., IV., and V. will be found results of corrosion tests selected from an extensive research, which was designed to cover the influence of a complete range

* J. Keir, Phil. Transactions, Royal Society, Vol. 80, p. 359.
† Michael Faraday, Phil. Magazine, Vol. 9, p. 53.
‡ Ulick R. Evans, Chemical Society, 1927.
§ Monnartz, Metallurgie, 1911, Vol. viii. pp. 161, 193.

TABLE II.—NITRIC ACID (HNO_3).

% Acid.	Ordinary Mild Steel.	14% Cr. Steel.		12% Cr., 12% Ni. Steel.		15% Cr., 11% Ni. Steel.		18% Cr., 8% Ni. Steel.	
	As Rolled.	As Rolled.	Hardened and Temp.	As Rolled.	As Softened.	As Rolled.	As Softened.	As Rolled.	As Softened.
TESTS AT 20° C.									
94·09	0·0029	0·0001	0·0001	0·0000	0·0000	0·0000	0·0001	0·0000	0·0000
69·80	0·0010	0·0001	0·0000	0·0001	0·0000	0·0000	0·0001	0·0000	0·0000
32·36	Max.	0·0001	0·0001	0·0000	0·0000	0·0000	0·0001	0·0000	0·0000
15·0	Max.	0·0082	0·0002	0·0000	0·0000	0·0000	0·0001	0·0001	0·0000
5·0	0·0572	0·0062	0·0014	0·0001	0·0001	0·0000	0·0001	0·0000	0·0000
1·0	0·0115	0·0060	0·0016	0·0001	0·0001	0·0000	0·0001	0·0001	0·0000
TESTS AT 60° C.									
94·09	0·1070	0·0008	0·0018	0·0001	0·0004	0·0001	0·0003	0·0001	0·0001
69·80	0·0416	0·0002	0·0003	0·0002	0·0001	0·0001	0·0001	0·0000	0·0000
32·36	Max.	0·0001	0·0001	0·0000	0·0001	0·0000	0·0001	0·0000	0·0000
15·0	Max.	0·0061	0·0003	0·0001	0·0001	0·0001	0·0001	0·0000	0·0000
5·0	Max.	0·0238	0·0006	0·0001	0·0002	0·0001	0·0001	0·0001	0·0000
1·0	Max.	0·0088	0·0036	0·0001	0·0002	0·0001	0·0001	0·0001	0·0000
TESTS AT BOILING POINT.									
94·09	0·7670	0·0300	0·0163	0·0027	0·0070	0·0020	0·0053	0·0202	0·0057
69·80	0·5915	0·0186	0·0087	0·0032	0·0049	0·0015	0·0030	0·0057	0·0009
32·36	Max.	0·0013	0·0091	0·0010	0·0010	0·0006	0·0006	0·0004	0·0003
15·0	Max.	0·0092	0·0050	0·0004	0·0005	0·0002	0·0002	0·0001	0·0000
5·0	Max.	0·0262	0·0321	0·0047	0·0002	0·0001	0·0001	0·0001	0·0001
1·0	Max.	0·0336	0·0084	0·0005	0·0005	0·0001	0·0001	0·0001	0·0000

of concentrations and over a range of temperatures from the normal to, and including, the boiling point of the corroding media.

TABLE I.

—	C.	Mn.	Si.	S.	P.	Cr.	Ni.
Electrolytic iron ..	0·03	0·02	0·02	0·003	0·02	—	—
Mild steel	0·27	0·64	0·09	0·04	0·03	—	0·11
14% chromium steel	0·11	0·25	0·22	0·015	0·02	14·70	—
12/12 chromium-nickel steel	0·10	0·18	0·23	0·016	0·014	12·47	12·25
15/11 chromium-nickel steel.....	0·12	0·30	0·19	0·012	0·018	15·00	11·00
18/8 chromium-nickel steel.....	0·17	0·27	0·37	0·015	0·019	17·43	8·07
6/24 nickel-chromium steel .	0·33	0·76	0·61	0·03	0·023	5·58	23·73
25/18 nickel-chromium steel	0·06	0·15	0·16	0·02	0·018	24·47	18·33

In all cases, the specimens used were machined cylinders, approximately 1·25 in. long × 0·5 in. diameter, and they were tested in the conditions as stated, with this machined surface, care being taken to keep the machining as uniform as possible, and were cleaned in alcohol before immersion in the acid. In each test, 80 ccs. of solution were used, and, therefore, the amount of the attack was limited by the acid content. This fact must, therefore, be taken into consideration when the results are studied. It will be found that the results in some cases are indicated by the word " max," instead of by a figure, and that is the indication that the maximum amount which the acid content could dissolve to form the normal salts had been removed from the specimen. For experimental purposes, it is no disadvantage to work with a limited quantity of reagent, since in such instances where the attack is great enough to modify the concentration seriously it is obvious that the steel in question would not, in practice, be employed to resist the acid in the concentration and at the temperature at which such attack is found to take place. In all cases, the loss in weight stated is in terms of grammes per square centimetre of surface.

It must be mentioned in connection with the acid tests that it is quite difficult, where attack takes place, to obtain the same quantitative results with the same steel under supposedly the same conditions. As the writer has pointed out on previous occasions, so many factors affect the action at the surface of the specimen. The results disclosed, however, in this article may be taken as truly indicative of the order of solution in the various acids of different concentrations and at various temperatures.

The acids selected in these experiments were nitric acid, phosphoric acid, sulphuric acid and hydrochloric

TABLE III.—PHOSPHORIC ACID (H_3PO_4).

% Acid.	Ordinary Mild Steel.	14% Cr. Steel.		12% Cr., 12% Ni. Steel.		15% Cr., 11% Ni. Steel.	18% Cr., 8% Ni. Steel.		24% Ni., 5% Cr. Steel.
	As Rolled.	As Rolled.	Hardened and Temp.	As Rolled.	As Softened.	As Rolled.	As Rolled.	As Softened.	As Softened.
				TESTS AT 20° C.					
Conc. (S.G. 1·75)	0·0036	0·0001	0·0001	0·0016	0·0000	0·0000	0·0000	0·0000	0·0015
80	0·2074	0·0012	0·2281	0·0028	0·0033	0·0001	0·0001	0·0000	0·0034
65	0·2440	0·1231	0·2975	0·0024	0·0023	0·0014	0·0001	0·0000	0·0003
50	0·2631	0·2280	0·2703	0·0022	0·0023	0·0017	0·0002	0·0000	0·0003
35	0·2344	0·0860	0·1682	0·0015	0·0010	0·0014	0·0001	0·0000	0·0003
20	0·1588	0·0167	0·0675	0·0008	0·0007	0·0013	0·0001	0·0000	0·0003
10	0·1012	0·0126	0·0206	0·0008	0·0005	0·0001	0·0001	0·0000	0·0004
5	0·0597	0·0002	0·0018	0·0000	0·0000	0·0001	0·0001	0·0001	0·0003
2·5	0·0291	0·0001	0·0000	0·0000	0·0000	0·0001	0·0001	0·0000	0·0004
1	0·0134	0·0001	0·0000	0·0000	0·0000	0·0001	0·0001	0·0001	0·0004
0·5	0·0066	0·0001	0·0000	0·0000	0·0000	0·0001	0·0001	0·0000	0·0005
0·25	0·0017	0·0000	0·0000	0·0000	0·0000	0·0000	0·0001	0·0001	0·0003
				TESTS AT 60° C.					
Conc. (S.G.1·75)	0·0104	0·0001	0·0001	0·0254	0·0001	0·0001	0·0000	0·0000	0·0037
80	0·3579	0·0025	0·0965	0·0480	0·0523	0·0002	0·0001	0·0001	0·0373
65	0·7829	0·2909	0·7775	0·0524	0·0411	0·0111	0·0465	0·0001	0·0251
50	0·7152	0·4350	0·7330	0·0344	0·0378	0·1318	0·0877	0·0001	0·0014
35	0·5160	0·1941	0·3930	0·0286	0·0225	0·0897	0·0001	0·0000	0·0015
20	0·2370	0·0592	0·0838	0·0145	0·0103	0·0875	0·0001	0·0000	0·0012
10	0·1090	0·0047	0·0255	0·0062	0·0044	0·0001	0·0001	0·0001	0·0013
5	0·0565	0·0002	0·0008	0·0000	0·0001	0·0000	0·0000	0·0001	0·0012
2·5	0·0284	0·0001	0·0000	0·0000	0·0001	0·0002	0·0001	0·0000	0·0018
1	0·0135	0·0000	0·0000	0·0000	0·0000	0·0001	0·0000	0·0000	0·0013
0·5	0·0071	0·0000	0·0001	0·0000	0·0000	0·0001	0·0000	0·0000	0·0016
0·25	0·0030	0·0000	0·0000	0·0000	0·0001	0·0000	0·0000	0·0000	0·0021
				TESTS AT BOILING POINT.					
Conc. (S.G.1·75)	0·8115	0·6215	0·6905	0·5455	0·7070	0·6880	0·8035	0·7150	0·3794
80	0·7850	0·6390	0·0498	0·8690	0·8455	0·8895	0·7350	0·7215	0·8700
65	0·7246	0·3132	0·2284	0·8821	0·7585	0·6470	0·6705	0·5915	0·1220
50	0·7740	0·1789	0·3465	0·6540	0·5337	0·5250	0·4710	0·4365	0·0442
35	0·4917	0·0909	0·3660	0·3712	0·3387	0·3375	0·3116	0·0001	0·0103
20	0·2222	0·0296	0·0648	0·1705	0·1376	0·0122	0·0001	0·0001	0·0040
10	0·1710	0·0072	0·0174	0·0052	0·0023	0·0001	0·0001	0·0000	0·0054
5	0·0394	0·0003	0·0028	0·0001	0·0001	0·0000	0·0000	0·0000	0·0050
25	0·0111	0·0002	0·0003	0·0001	0·0001	0·0001	0·0001	0·0000	0·0078
1	0·0131	0·0001	0·0002	0·0001	0·0001	0·0001	0·0001	0·0001	0·0059
0·5	0·0069	0·0001	0·0001	0·0000	0·0000	0·0001	0·0001	0·0000	0·0025
0·25	0·0024	0·0001	0·0002	0·0000	0·0001	0·0000	0·0000	0·0000	0·0025

acid, and the concentrations of the acids employed were as follows, the per cent. concentration referring to the weight of 100% acid in 100 grms. of the solution in question.

(*a*) *Nitric Acid.*—The following by specific gravity :—
% concentration .... 94·09 .. 69·8 .. 32·36 .. 15
° Twaddell.............. 100 .. 84 .. 40 .. 17
5% and 1% by dilution of 15% solution.

(*b*) *Phosphoric Acid.*—The following by specific gravity :
% concentration 65 .. 50 .. 35 .. 20 .. 10 .. 5
° Twaddell ...... 95 .. 67 .. 43 .. 23 .. 10 .. 5
2·5%, 1%, 0·5%, 0·25% by dilution of 5% solution. The concentrated acid used was the ordinary concentrated acid, s.g. 1·75, and the 80% acid was made from this by the addition of a calculated amount of water.

(*c*) *Sulphuric Acid.*—The following by specific gravity :—
% concentration ...95·6 .. 80 .. 65 .. 50 .. 35 .. 20 .. 10 .. 5
° Twaddell 168 .. 146 .. 112 .. 80 .. 53 .. 29 .. 14 .. 7
2·5%, 1%, 0·5%, and 0·25%, by dilution of 10% solution.

(*d*) *Hydrochloric Acid.*—The following by specific gravity :—
% concentration .... 34·45 .. 20 .. 10 .. 5
° Twaddell .... 35 .. 20 .. 10 .. 5
2·5%, 1%, 0·5%, and 0·25% by dilution of 10% solution.

Nitric Acid.—A consideration of the data disclosed in Table II. will show that at the ordinary temperature mild steel is relatively resistant to the highest concentrations of acid, but that it is badly attacked in the more dilute acids. The 14% chromium steel is seen to be far more resistant, but it will be observed that even with 14% of chromium there is a substantial attack in the more dilute solutions. As regards the three nickel-chromium steels, it is clear that practically complete resistance is obtained in all cases over the whole range of concentrations. When the temperature is elevated to 60° C., it will be seen that the order of the response of the steels is much the same, although the resistance is not quite as great, except in the case of the steel containing 18% of chromium and 8% of nickel. As regards the boiling acids of various concentrations, it will be seen, as will be anticipated, that the attack is greatly intensified, and particularly is this so as regards the mild steel and the 14% chromium steel. Even the chromium-nickel steels are not resistant over the whole range of concentration, although it will be seen that the last two chromium-nickel steels in the table, particularly the 18% chromium 8% nickel composition, are extremely resistant in the boiling acid up to a concentration of somewhere between 30 and 70%. To sum up, therefore, it is clear from these experiments that whilst the

TABLE IV.—SULPHURIC ACID (H_2SO_4).

% Acid.	Elect. Iron.	Ordinary Mild Steel.	14% Cr. Steel.		12% Cr., 12% Ni. Steel.		15% Cr., 11% Ni. Steel.		18% Cr., 8% Ni. Steel.		24% Ni., 5% Cr. Steel.	25% Ni., 18% Cr. Steel.
	As Forged.	As Rolled.	As Rolled.	Hardened and Temp	As Rolled.	As Softened.	As Rolled.	As Softened.	As Rolled.	As Softened.	As Softened.	As Softened.
TESTS AT 20° C.												
95·6	0·0011	0·0010	0·0018	0·0022	0·0001	0·0018	0·0013	0·0010	0·0019	0·0017	0·0017	0·0014
80	0·0015	0·0008	0·0034	0·0094	0·0001	0·0011	0·0053	0·0033	0·0049	0·0047	0·0012	0·0007
65	0·0226	0·0012	0·0035	0·0052	0·0043	0·0027	0·0054	0·0040	0·0115	0·0153	0·0005	0·0038
50	0·0432	0·1163	0·2840	0·2798	0·0048	0·0091	0·0194	0·0357	0·0878	0·0820	0·0005	0·0015
35	0·0348	0·1380	0·3901	0·3930	0·0022	0·0079	0·0077	0·0109	0·0662	0·0541	0·0005	0·0012
20	0·0331	0·0838	0·4375	0·4595	0·0018	0·0074	0·0043	0·0056	0·0477	0·0180	0·0004	0·0007
10	0·0087	0·0518	0·2728	0·2526	0·0018	0·0032	0·0023	0·0020	0·0262	0·0021	0·0003	0·0003
5	0·0056	0·0384	Max.	0·1430	0·0017	0·0003	0·0020	0·0019	0·0154	0·0027	0·0003	0·0003
2·5	0·0036	0·0290	0·0710	Max.	0·0008	0·0005	0·0019	0·0015	0·0030	0·0010	0·0009	0·0003
1	0·0028	0·0146	Max.	Max.	0·0007	0·0009	0·0019	0·0011	0·0002	0·0004	0·0003	0·0003
0·5	0·0017	0·0127	Max.	Max.	0·0007	0·0007	0·0008	0·0007	0·0000	0·0004	0·0002	0·0002
0·25	0·0013	0·0056	Max.	Max.	0·0004	0·0006	0·0005	0·0006	0·0001	0·0000	0·0003	0·0001
TESTS AT 60° C.												
95·6	0·0027	0·0030	0·0058	0·0445	0·0051	0·0048	0·0014	0·0021	0·0044	0·0029	0·0027	0·0013
80	0·0048	0·0036	0·0434	0·0034	0·0242	0·0016	0·0685	0·0731	0·0416	0·0353	0·0023	0·0209
65	0·0122	0·0077	0·0227	0·0242	0·0166	0·0376	0·0888	0·0851	0·1443	0·1620	0·0021	0·0215
50	0·1033	0·0838	0·4480	0·3855	0·0321	0·0540	0·1191	0·1285	0·4580	0·4090	0·0014	0·0250
35	0·2274	0·7985	0·9205	0·9950	0·0138	0·0408	0·0255	0·0432	0·3026	0·1721	0·0017	0·0224
20	0·1087	Max.	0·6275	0·6610	0·0203	0·0660	0·0416	0·0437	0·1379	0·1228	0·0016	0·0074
10	0·0505	Max.	Max.	Max.	0·0194	0·0081	0·0199	0·0312	0·0637	0·0491	0·0013	0·0054
5	0·0212	Max.	Max.	Max.	0·0123	0·0218	0·0212	0·0080	0·0779	0·0297	0·0015	0·0039
2·5	0·0171	Max.	Max.	Max.	0·0043	0·0184	0·0094	0·0153	0·0604	0·0147	0·0015	0·0034
1	0·0087	Max.	Max.	Max.	0·0031	0·0119	0·0048	0·0076	Max.	0·0042	0·0015	0·0020
0·5	0·0058	Max.	Max.	Max.	0·0082	0·0088	0·0051	0·0065	0·0130	0·0029	0·0010	0·0012
0·25	0·0058	Max.	Max.	Max.	0·0043	0·0020	0·0025	0·0041	0·0062	0·0013	0·0010	0·0012
TESTS AT BOILING POINT.												
95·6	—	—	—	—	—	—	—	—	—	—	—	—
80	0·0913	0·0575	1·3560	1·5915	0·4725	0·6015	0·5570	0·6555	0·7305	0·7795	0·5045	0·6190
65	0·0551	0·0348	1·0295	0·8855	0·8610	1·1715	0·4205	0·6035	1·1330	1·1215	0·1513	1·1695
50	0·0679	0·0609	0·9405	1·0015	0·4423	0·4055	0·4240	0·3980	0·5865	0·4860	0·2792	0·6645
35	1·3875	1·1630	1·3115	0·7560	0·5785	0·5085	0·6205	0·6790	0·7855	0·6310	0·0920	0·6472
20	0·7500	Max.	0·4885	Max.	0·3820	0·3328	0·4670	0·4580	0·5360	0·5080	0·0081	0·0920
10	Max.	Max.	0·4838	Max.	0·0521	0·2623	0·2078	0·2592	Max.	0·2394	0·0100	0·0047
5	Max.	Max.	Max.	Max.	0·0202	0·1313	0·0949	0·1421	Max.	0·1343	0·0056	0·0043
2·5	Max.	Max.	Max.	Max.	0·0061	0·0169	0·0161	Max.	Max.	0·0622	0·0124	0·0021
1	Max.	Max.	Max.	Max.	0·0078	0·0005	0·0059	Max.	Max.	0·0271	0·0062	0·0017
0·5	Max.	Max.	Max.	Max.	0·0039	0·0093	Max.	Max.	Max.	Max.	0·0061	0·0013
0·25	Max.	Max.	Max.	Max.	Max.	Max.	Max.	Max.	Max.	Max.	0·0057	0·0023

14% chromium steel marks a very great advance as regards the provision of material for resisting nitric acid of various concentrations and at various temperatures, yet the ranges both of concentration and of temperature which the steel will withstand are greatly increased when nickel is alloyed with the steel in addition to the chromium, and particularly when the chromium content is increased. It will be noticed that the resistance of the steels is given for two conditions—*i.e.*, in the condition " as rolled " and as " heat-treated."

Phosphoric Acid.—The data disclosed in Table III. clearly indicate that mild steel fails in all concentrations and at all temperatures down to the normal, although there is an indication that when only traces of phosphoric acid are present the resistance may be sufficiently satisfactory for industrial purposes. The marked advance as regards resistance when 14% of chromium is added is well demonstrated, although over a range of concentration from 10 to 80% the attack is considerable. A comparison of the three chromium-nickel steels again shows the advantage of the addition of nickel, and brings out the interesting feature that the 18% chromium 8% nickel steel is the most resistant of the three.

The steel in the last column of this table—namely, the one containing 24% of nickel and 5% of chromium—is included with the idea of indicating the comparative effect of greatly increasing the nickel content and reducing the chromium content. It will be seen that such a steel, whilst superior to the plain chromium steel in certain cases, is much less effective than the previous three chromium-nickel steels under consideration. Up to 60° C., 14% chromium steel would give a satisfactory life with concentrated acid or with acid of less than 5% strength. At boiling point, its range of usefulness would appear to be confined to solutions of not more than about 2·5% strength; in general, the " as rolled " condition seems preferable to the hardened and tempered. Below 5% the first three nickel-chromium steels show an excellent resistance, even at boiling point. Above this concentration, the results vary somewhat, but the 18% chromium 8% nickel steel is apparently again the most satisfactory. It would not, however, appear to be safe to use with acid of more than, say, 30% strength, at 60° C. or over, as the indications are that passivity phenomena render the resistance uncertain.

Sulphuric Acid.—It is interesting to note from the data in Table IV. that over a wide range of concentration the pure electrolytic iron is superior to the ordinary mild steel at ordinary temperatures: how the 14% chromium steel is less resistant even than the mild steel. The chromium-nickel and the nickel-chromium steels are certainly of interest as being resistant to the acid in low concentrations. With the higher temperatures the resistance falls and cannot be considered good enough for industrial application.

Hydrochloric Acid.—At ordinary temperatures, as indicated in Table V., the three nickel-chromium steels have a limited sphere of usefulness—namely, when the concentration of the acid does not exceed about 5% and absolute purity of the product is not essential. The 12% chromium 12% nickel steel is the most satisfactory, and shows a very good resistance below 0·5%. Mild steel and ordinary stainless steel must be considered useless over the range studied. At 60° C. and boiling point, none of the steels tested can be considered of any use for hydrochloric acid of more than 0·25% strength, though there is an indication that at 60° C. it might be possible to use the nickel-chromium steels with more dilute solutions.

The object of the writer in presenting these data is essentially to indicate, in the first place, the great advance

TABLE V.—HYDROCHLORIC ACID (HCl).

TESTS AT 20° C.

% Acid.	Ordinary Mild Steel.	14% Cr. Steel.		12% Cr., 12% Ni. Steel.		15% Cr., 11% Ni. Steel.		18% Cr., 8% Ni. Steel.	
	As Rolled.	As Rolled.	Hardened and Temp.	As Rolled.	As Softened.	As Rolled.	As Softened.	As Rolled.	As Softened.
34·45	0·1448	0·3112	0·2819	0·0597	0·0750	0·1873	0·1550	0·1253	0·1710
20	0·0762	0·2762	0·2414	0·0059	0·0099	0·0188	0·0117	0·0170	0·0220
10	0·0413	0·2311	0·2543	0·0015	0·0024	0·0020	0·0022	0·0058	0·0039
5	0·0314	0·1803	0·1431	0·0006	0·0011	0·0015	0·0011	0·0017	0·0014
2·5	0·0221	Max.	Max.	0·0004	0·0009	0·0010	0·0008	0·0018	0·0011
1	0·0150	Max.	Max.	0·0002	0·0006	0·0003	0·0007	0·0023	0·0016
0·5	0·0107	Max.	Max.	0·0003	0·0003	0·0005	0·0005	0·0006	0·0004
0·25	0·0081	0·0099	0·0093	0·0002	0·0003	0·0016	0·0003	0·0004	0·0002

TESTS AT 60° C.

34·45	1·1075	1·2860	1·2995	0·8305	0·8960	0·9565	0·9920	0·9625	0·9065
20	0·7835	0·8125	0·8425	0·3340	0·3761	0·4415	Max.	0·3226	0·2638
10	Max.	Max.	Max.	0·0456	0·0353	0·0616	0·0405	0·0759	0·0630
5	Max.	Max.	0·1852	0·0186	0·0139	0·0265	0·0319	0·0245	0·0136
2·5	Max.	Max.	Max.	0·0052	0·0066	0·0058	0·0152	0·0085	0·0071
1	Max.	Max.	Max.	0·0010	0·0052	0·0031	0·0097	0·0054	0·0266
0·5	Max.	Max.	Max.	0·0039	0·0052	0·0043	0·0117	0·0105	0·0052
0·25	Max.	0·0087	0·0097	0·0024	0·0031	0·0033	0·0089	0·0016	0·0018

TESTS AT BOILING POINT.

34·45	1·0445	1·0940	1·2545	0·9278	1·0230	0·9998	1·0370	0·9290	0·9695
20	0·8115	Max.	Max.	0·8140	0·8965	0·7495	Max.	0·7375	0·7180
10	0·4005	Max.	Max.	0·3604	Max.	0·3739	Max.	0·4085	Max.
5	Max.	Max.	Max.	Max.	0·1837	Max.	Max.	0·1868	0·1856
2·5	Max.	Max.	Max.	Max.	Max.	Max.	Max.	0·1024	0·1167
1	Max.	Max.	Max.	0·0024	Max.	0·0077	Max.	0·0440	Max.
0·5	Max.	Max.	Max.	0·0174	Max.	0·0180	Max.	0·0224	Max.
0·25	Max.	Max.	0·0092	0·0092	Max.	0·0054	0·0075	0·0087	Max.

(*Continued on page* 26.)

Phosphor Bronze for Bearings

Composition and Function of Hard and Soft Constituents
Adjustment of Tin and Phosphor Contents

By H. C. Dews

Half a century ago, before non-ferrous alloys had ever been examined under the microscope, when metallurgical analysis was still a crudity, before the days of the constitutional diagram, at the very birth, in fact, of the metallurgical science we know to-day, phosphor bronzes were first manufactured commercially. Bronzes, of course, are as old as civilisation itself, but that the non-metal phosphorus should ever have been incorporated in these alloys can only be regarded with surprise. It is still more a matter of surprise that the particular mixture used should have been confirmed by subsequent enlightened research as the optimum composition for phosphor bronze. Refinements have been introduced in recent years in consequence of the close study which has been given to these alloys, but the essential basis alloy is still much the same as when it was first developed. It was originally found that bearings gave successful service when made from phosphor bronze, and to-day the more strictly controlled alloys are used almost exclusively for this purpose.

The simple copper-phosphorus alloys were studied during the eighteenth century, but up to the beginning of the nineteenth century, although several students, among whom Pellitier deserves especial mention, boldly prophesied for them a useful future, their use in industry had not been tried. In 1848 a patent was taken out by Parkes of Birmingham for the use of phosphorus for improving copper and brass castings, but he did not mention bronze. The first definite record of the use of phosphor bronze is dated a few years later, in 1854, when M. Roulz used phosphor bronze on the Orleans Railway. About this time several European governments took up the study of these alloys. Experiments were proceeding at Woolwich Arsenal under the supervision of Weston and Abel, the Belgian Government commissioned three chemists, Monifore, Levi, and Kunzel, to conduct researches on this subject, and later the same three investigators worked on phosphor bronzes for the Russian Government. The work done by Professor Kunzel during this period was of such outstanding importance that he is now generally acknowledged to be the inventor of phosphor bronze. Commercial production was started by the brothers Dick, who founded the Phosphor Bronze Co. in Birmingham and the Phosphor Bronze Smelting Co. in Philadelphia. Both firms used the patents taken out first in France in 1870 by Monifore, who was a colleague of Kunzel.

Some little time after the introduction of true phosphor bronzes there sprung up the practice of using a little phosphorus to de-oxidise all classes of bronze alloys. There was naturally a desire to distinguish these improved bronzes from the older and inferior alloys in the founding of which no precautions to secure "de-oxidation" had been observed. The terms "phosphorised" or "phosphor" bronze naturally came into use, and in spite of the fact that there was an older and more correctly named class of alloys under this name, the term "phosphor bronze" became commonly misapplied to alloys in the melting of which phosphorus had certainly been used, but which contained no phosphorus in their final composition. These "phosphorised" alloys are from a metallurgical and mechanical point of view in an entirely different class from those bronzes which carry a definite and appreciable amount of phosphorus. It is to the latter class that the name phosphor bronze properly belongs.

RANGE OF COMPOSITION.

The range of composition which provides the phosphor bronzes useful for bearings lies between 9 and 14% tin, with from $\frac{1}{10}$ to 1% phosphorus, and the remainder copper. The most popular alloy, and one which gives excellent service under a great variety of conditions, has the composition and properties detailed in Table I.

TABLE I.

Composition.		Mechanical Properties.	
Tin	11%	Maximum stress	17 tons per sq. in.
Phosphorus	0.3%	Yield point	10 "
Lead	0.2%	Elongation	10%
Iron	<0.1%	Elastic limit in compression	7 tons per sq. in.
Zinc	<0.1%		
Copper	remainder	Brinell	85

It has gradually become clear from accumulated experience in the use of bearing metals of all types that no matter from what class of alloy the bearing metal is made certain broad requirements essential to successful service can be specified. The principal desideratum is that the alloy shall have a microstructure of a certain distinctive type. This consists of a more or less plastic ground mass, in which is embedded a number of relatively hard isolated particles. The function of the hard particles—or hard network, as it may sometimes be—is to resist the abrasive and tearing action of the revolving shaft and to maintain a true-to-size working surface. The matrix of the alloy should be ductile enough to "bed" into place and to take up small errors in alignment of the bearing. The matrix should be sufficiently soft to wear away very slightly when the bearing is run in, and to leave the hard parts standing in relief. In this way the bearing surface is reduced and frictional loss is lessened, while the channels between the hard relief provide means of circulating lubricant over the whole working surface.

In Fig. 1 is shown a photomicrograph of a sample of phosphor bronze of the composition detailed in Table I., and it can be seen how the alloy fulfils the bearing metal requirements. The microstructure consists of a ground mass α of relatively soft constituent, in which is embedded a network δ of hard material. The α solid solution, which constitutes the matrix in all sand-cast bearing bronzes, contains about 7% tin. The hard material consisting of δ solid solution contains a higher proportion of tin than the α matrix. Along with the δ is also the whole of the phosphorus in the form of copper phosphide. The hard material is shown at a high magnification in Fig. 2, and the δ solid solution and the copper phosphide Cu3P can be distinguished.

The α solid solution which forms the matrix of the bronze is comparatively soft. Its Brinell hardness is about 50 to 70, and it possesses considerable ductility. The Brinell hardness of the hard materials—the δ solid solution and the phosphide—are respectively about 220 and 130. By a suitable adjustment of the tin and phosphorus contents of the alloy any proportion of hard material, and in

consequence any degrees of hardness in the alloy as a whole, may be produced. From the point of view of cheapness, it would appear to be desirable to obtain as much as possible of the required hardness by means of phosphorus, and as little as possible by means of expensive tin. There is, however, a serious objection to the hardness produced by phosphorus. Bronzes containing large amounts of phosphorus are generally brittle, and liable to fracture under shock, whilst, on the other hand, a much higher degree of hardness may be secured by tin additions without dangerous brittleness. The high tin bronzes, therefore, although more expensive, are much tougher than the high phosphorus alloys.

permitted. Several leading metallurgists question the advantages supposed to be derived from lead additions, but there is no doubt that these alloys have achieved a good deal of popularity for many purposes. The nickel-bearing phosphor bronzes have only lately received attention, and their value is only just being realised. With the exception of these two metals, lead and nickel, all other metals should be regarded as impurities. Some impurities are, without doubt, seriously injurious, and others are at the best unnecessary. The commonest impurities are zinc, iron, and, in smaller amounts, antimony, arsenic, and also such extraneous inclusions as sand from moulds and scum and slag from the metal.

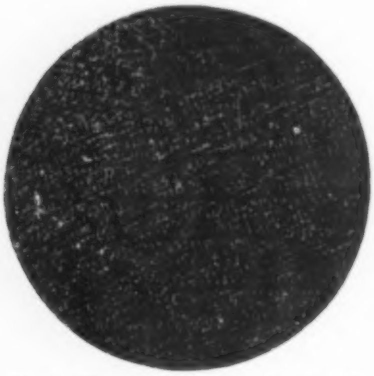


Fig. 1—Phosphor bronze showing the soft matrix of solid solution (dark) and the hard constituents (light). Magnification 75.

Fig. 2—The hard constituents in phosphor bronze. Magnification 1000.

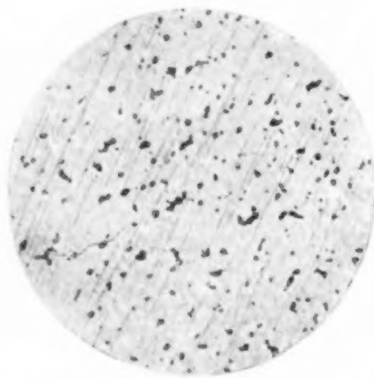


Fig. 3—Leaded phosphor bronze, showing the lead globules. Magnification 75.

CONTENTS ADJUSTED TO SUIT CONDITIONS.

A careful adjustment of the tin and phosphorus contents of a bronze, in accordance with the service that the bearing has to give, without extravagant use of expensive tin, requires a nice metallurgical control of the composition, and, if such control is carried out successfully, important savings from a commercial point of view may result. When considering the choice of a suitable composition, it is primarily necessary to know to what extent the bearing may be subjected to shock and repeated impact stresses. If the working conditions are very severe, then it is necessary to keep the phosphorus low and employ a fairly high tin content. Examples of such highly stressed parts are found in axle bearings and transmission gearing of road transport vehicles, such as lorries and buses, where continual bumping on the road repeatedly subjects the bearing to heavy shocks. For small stationary machinery bearings, which are not liable to such shocks, the phosphorus may be increased and the tin content lowered. Whatever adjustment is made in the relative proportions of tin and phosphorus, the microstructure of the alloy should continually be studied, in order that the essential " bearing metal " structure may be always adhered to. Neither must too much soft material, on the one hand, nor too much hard constituents on the other hand, be produced. To retain this essential structure it will be found that in no case will the tin exceed 14%. When the tin is pushed to its upper limit the phosphorus must be kept low. With about 11% tin the phosphorus may be increased to about ½%, but if more phosphorus is added, then the tin must be still further lowered until with 1% phosphorus—which is the maximum amount desirable in any bearing bronze—the tin content should be no more than 9—10%.

EFFECT OF LEAD.

The best quality phosphor bronzes which are chosen for high duty should generally be as free as possible from metals other than tin, phosphorus, and copper; although, for certain purposes, lead and nickel may be sometimes

The effect of lead on the mechanical properties of phosphor bronze is immediately noticed in a reduction of its maximum stress and yield point. The co-efficient of friction and resistance to abrasive wear are in general improved. A simple phosphor bronze, for example, containing 5—10% lead, will retain a perfectly true working surface for long periods, provided that the load is not too heavy. For locomotive slide valves and similar purposes, where a steam-tight joint is required, leaded phosphor bronze is generally chosen. A typical composition would be—

	%
Tin	10
Lead	7
Phosphorus	1
Copper	82

The lead content of these alloys should never be below 5%, and may be as high as 10%. Smaller amounts of lead bring about no advantages to compensate for the loss of strength due to the lead inclusion. Structurally, lead remains free in bronze as globules of pure metal scattered throughout the alloy, and a microsection, polished but not etched, clearly shows the lead inclusions. In Fig. 3 is shown the microstructure of the alloy of the composition given above.

An objectionable feature of lead in phosphor bronze is the difficulty it imposes on the founding of good castings. Lead and phosphorus combine to produce a very fluid slag, which is liable to run with the metal into the moulds and to leave gritty patches in the castings. These slag inclusions soon cause scoring of bearings and shafting in service, and the replacement rendered necessary may be both costly and inconvenient. If the lead content is too high, it may also segregate into large pools in the castings, and thereby cause bearings to wear unevenly.

NICKEL ADDITIONS.

The addition of nickel to phosphor bronze for bearings has recently come into prominence. The present blaze

of publicity upon all uses of nickel, which is kept alight by the highly organised commercial development organisations, makes it seem likely that, if there is any real advantages in nickel additions, these advantages will not long remain obscure. The addition of nickel began first in the United States, where there are now several well-known producers of bearings making nickel phosphor bronzes on a large scale. In this country tentative trials have already been made, and results are gradually becoming available for detailed consideration. It is unfortunate that the first claims for the advantages of nickel were vague, and savouring slightly of quackery. It is common to find, for example, the terms "densifying" and "grain closing" applied to the effects of nickel, and there are on the market one or two so-called "densifiers," which consist of nothing more than alloys containing a large proportion of nickel and phosphorus with the remainder copper. Such commercial methods are not likely to receive extensive support in these enlightened days, and it should scarcely be necessary to point out that the real effect of nickel can only be ascertained as a result of careful research, carried out under strict metallurgical control. As nickel additions add to the cost of phosphor bronze, it is all the more necessary that a proper scientific understanding of its effects be assimilated before intensive manufacture be commenced.

The term "densification" has doubtless been applied to the effect of nickel on account of its action on the grain size of cast bronze. With about 2% nickel the crystal structure of a normally cast bronze is considerably finer than in a similar bronze nickel free. The distribution of the phosphorus is also affected by the presence of nickel. Whereas, in an ordinary phosphor bronze all the phosphorus is present as copper phosphide, in a nickel phosphor bronze the phosphorus begins to appear as nickel phosphide. Nickel has a greater affinity for phosphorus than has copper, and when sufficient nickel is present the whole of the copper phosphide may be broken down and replaced by nickel phosphide. The practical advantages of nickel phosphor bronzes rest on the relative merits of the two phosphides, coupled with the effect of the smaller grain size and consequent finer dispersion of the hard phosphides.

Nickel phosphor bronzes have not yet been used as extensively for bushings as for gears. For the latter purpose it is usual to add 1—2% nickel to the ordinary

TABLE II.

Composition.			Mechanical Properties.		
Tin.	Nickel.	Phosphorus.	Maximum Stress.	Yield.	Elongation.
%	%	%	Tons per Sq. In.	Tons per Sq. In.	%
11	1	0.25	17	14	3
10	2	0.25	21	13	7

bearing bronzes containing about 10% tin. Gears made from these alloys are said to have a greater resistance to wear and to pitting than ordinary phosphor bronze gears. The mechanical properties of such alloys are shown in Table II.

THE INFLUENCE OF ZINC.

The impurity most liable to be found in a phosphor bronze (and incidentally the most injurious impurity) is zinc. A small quantity of zinc seriously reduces the antifriction properties, and if present to the extent of about 1% it causes rapid seizing and tearing of bearings which run at more than moderate speeds. For high-speed bearings no more than a trace of zinc should be present in the bronze, and even for less severely worked parts the zinc is best kept down to as low limits as possible.

It is sometimes claimed that the presence of zinc improves the casting properties of phosphor bronze, but such a statement rests entirely on a misconception. When the foundry conditions are properly controlled, zinc may be extremely objectionable. If the foundry practice is already thoroughly bad, then zinc may be welcomed as an ally in producing castings which appear superficially improved. When such bearings are put into service, however, rapid failure invariably results. The phosphor bronzes which are used for bearings should, of course, be distinguished from the gun-metals, which contain zinc as an essential constituent, and which are used under entirely different conditions from phosphor bronzes.

Most cast phosphor bronzes contain a small amount of iron, unless very special precautions are taken towards its exclusion. The use of iron stirrers in the foundry, the contamination of scrap metal with chips of steel, and so on, are likely to leave traces of iron in the alloy. This iron remains undissolved as tiny inclusions, which are harder than the remainder of the alloy and are liable to score the shafting running in such bearings. The iron content of these alloys should, therefore, be kept as low as possible.

SULPHUR IN CHIMNEY GASES

During the past few months there has been great agitation against the proposal to erect a new super-power station at Battersea, because of the damage that may be caused by acid sulphur gases discharged from the chimney. This matter has largely been brought to a head because of the present litigation in which the Manchester Corporation is involved concerning the Barton Power Station, just outside the City of Manchester. It is alleged that the sulphurous and sulphuric acid in the chimney gases has damaged the crops of a farmer, and the case has been taken up by the Farmers' Federation, the present situation being that the Manchester Corporation lost the case, then won on the appeal, and finally the Farmers' Federation have taken the matter to the House of Lords, whose decision has yet to be given.

It is obvious that the question of sulphur in chimney gases is a new problem that has arisen, says David Brownlie in "Burns' Engineering Magazine," and one that is becoming increasingly serious in view of the enormous size of modern super-power stations. Not so long ago some of the largest electricity stations in the world were burning not more than 200–300 tons of coal per day, but we have now got stations with 2,000–3,000 tons per day, and the immediate possibility of 5,000 tons per day or over. If we take a reasonable figure for the total sulphur in coal as 1½%, this corresponds, at 2,000 tons per day, to 30 tons of sulphur in this time, or 90 tons calculated as sulphuric acid, equal to the total amount of acid gases discharged from about 125,000 private houses—that is, a huge town. The effect, of course, is bad enough with a consumption of, say, 100 tons of coal per day, but when several thousand tons are concerned the result is apt to be disastrous.

One of the great advantages always claimed for electricity, quite rightly, is the ease and convenience with which the energy can be conveyed over long distances by means of simple wires, and it is obviously a stupid policy, from both the scientific and the national point of view, to erect a huge power station in the middle of a large town.

The three major problems in connection with the generation of electricity by means of condensing steam turbines according to standard practice are: (1) Sulphur in chimney gases; (2) loss of over 50% heat; (3) loss of valuable by-products that could be obtained if the coal was submitted to low-temperature carbonisation in front of the boiler setting, instead of being burnt direct in the raw state.

This subject of sulphur might easily bring forward again certain alternative methods of operating large boiler plants that have been suggested from time to time. The first of these is, of course, low-temperature carbonisation, which would eliminate a considerable proportion of the sulphur, the gases and vapours evolved by the carbonisation, for example, containing practically all the volatile sulphur, which could then be removed from the residual gas after extraction of the low-temperature tar and the light oils in a relatively easy manner; but much research work is required on this matter.

Bar Grinding Shop exclusively engaged upon the grinding of rods and bars up to 45 ft long. The bar being carried was ¾ ins. diameter and 35 ft. long.

Production by Centreless Grinding

By Hugh Pratt

Of Pratt, Levick & Co., Ltd., Chester.

Much interest has been shown and many articles have been written of late years on this subject. It may also be said that much experience has been gained, experience which has been in the main very encouraging, but on occasion very disappointing. This variation in the results obtained is inevitable to the introduction of new methods, and is in no wise due, as many people conclude, to the fact that the method is unstable, but rather to the fact that all methods have their limitations, and that we are sometimes inclined to let the "wish be father to the thought" in harnessing the new method to a job for which it is inherently unsuitable.

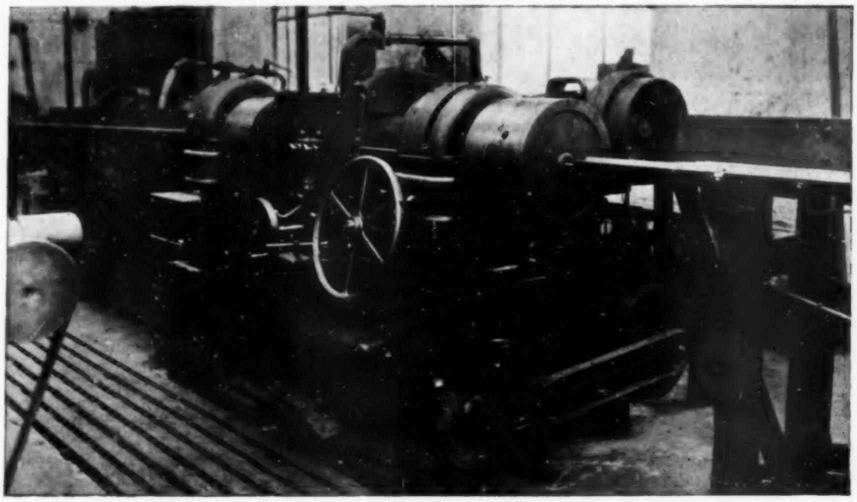
It is unfortunate that the makers of most modern machinery, in their endeavours to sell machines, are not quite so careful in their statements of the capabilities of their products as could be wished, and in their anxiety to be allowed a chance of making good, sometimes credit their machine with powers it does not possess, with subsequent disappointment to themselves and their clients, not only in the particular machine in question, but in the process itself. Be that as it may, much real progress has been made both in the process itself and in the realisation of its limitations.

The process can be divided into two main categories: one, the grinding of rods and bars in continuous lengths of from 3 ft. to 40 ft. to fine limits of diameter; and the other, the grinding of comparatively short details in a repetition manner. Each of these categories has its own particular problems and its own particular merits, but it is fatal to conclude that the same methods or machines can be employed and can give satisfaction under either of them.

In the case of grinding rods and bars it is essential that the work be driven positively and continuously without reference to the depth of cut, as the resistance to its rotation and feeding varies through very wide limits, according to its size, length and straightness, stiffness and weight; as, for example, a rod ⅛ in. dia. × 6 ft. long, and a bar 1⅝ in. dia. × 25 ft. long. In the case of the second method, the grinding of short details, these factors are of much less importance; hence the usual method is to impart both rotary motion and feed to the work through the grinding-wheel itself. This operation is in the nature of a very successful compromise, but, like most compromises, must be used with a full conception of its limitations. The motion is obtained by burying the grinding-wheel to some extent in the work, and it will readily be seen that the amount of depth of cut must be more when the resistance to motion is more. Thus, when the factors of diameter, length, straightness, and weight exceed a certain point, it is not possible to regulate the depth of cut to the finest "blow," as the result of so doing would be to deprive the work of motive power, and slight flatting would ensue. But so long as an attempt be not made to get a quart out of a pint pot, there is no finer method of quick and accurate production extant than the modern centreless grinding machine of the B.S.A. or Churchill type, and why should it be expected that this type of machine should do work it was originally never designed to do, any more than that a 6-in. lathe, which would make quite a good job of a ⅝ in. bolt 3 in. long, should produce accurately and economically a shaft ⅝ in. dia. 8 ft. long.

The short method machine is doing work within its capacity far ahead of the work done by any other type of machine where great accuracy and production are the measure of efficiency, and without it many modern productions would be out of the market altogether. Much has been done by designers to perfect this type of machine, and to simplify the setting-up of work and the truing of wheels thereon, both for plain straight work and for formed work, in the production of which it is especially applicable, and there can be no doubt that further great advances will be made in the same direction.

Turning to the other type of centreless grinding, the production of rods and bars in long lengths, this opens another field altogether. The method of dealing with this type of grinding was first made commercially possible by that great mechanician, Mr. Hans Renold, of chain-making fame, whose ingenuity and capacity for the invention of unique methods of production are so well known. Many years ago he produced a type of machine which was possibly the forerunner of the whole line of centreless grinders, and which still holds its own on production, and modern machinists have much to thank him for. In most things it is found that if one meets difficulties singly they are easy to surmount, but should they all combine in one united effort at the same time, then the case is not nearly



Roller Type Bar Grinding Machine in which circular and longitudinal motion is imparted by fixed heads which comprise a roller feed mechanism.

so simple, and calls for careful analysis and procedure. Diameter, length, weight, flexibility, stiffness, each as such and in itself, form no very great obstacle, however accurately they must be controlled, but when all these factors combine and call in the aid of inherent stress in the material in one rod or bar, then the way of the machinist is indeed hard. Only by a process of elimination and attrition can they be overcome, and by a realisation that a plan of attack eminently suitable to deal with $\frac{5}{8}$ in. dia. × $3\frac{1}{2}$ in. long will not help.

The first essential is that the rod or bar be got as straight as possible, or straighter, and kept straight throughout the operation. This is bound up with the inherent stresses in the bar, which may have been produced by the rolling or drawing, as the case may be. In some cases, due to the heat-treatment which bars may have received, it is well-nigh impossible to get them absolutely straight, but every little they depart from that state militates against the quality and quantity of the work produced. This straightening process is effected by reeling; the rods being reeled both before grinding, and often several times between passes. The reeling machines must be kept in first-class order, and not allowed to get into the state common in many steelworks.

The grinding is done alternatively from black bar or from cold-drawn bar. The former is adopted only in those materials which are difficult to draw, as the allowance necessary to ensure the finished rod cleaning up will of necessity be greater than when drawn material is used, due to the inaccuracy and imperfection of rolling, scale, pitting, etc. There is, however, another reason for grinding from the black, and that is in cases where material has to give certain tests which cannot be obtained from the drawn product. The allowance necessary when using black bar must be anything from 25 to 35 thousandths above the finished size of the bar, according to the quality of the rolling. But with drawn bar, which can be very generally used for most purposes, a much smaller allowance can be used. On small diameters up to $\frac{1}{2}$ in. an allowance of 3 to 6 thousandths is adequate, whilst for sizes up to $1\frac{5}{8}$ in. 4 to 8 thousandths is found suitable.

In the actual grinding over batches of material it is found better to take several cuts of a small depth, rather than to attempt the removal of much stock at a pass, as by so doing the initial inaccuracy of the bars is gradually and uniformly eliminated, leaving the bars after each pass much more uniform throughout the batch. This is essential, as it will be readily seen that the keeping of size depends largely upon the grinding-wheel having as nearly as possible a uniform amount of work to do throughout the pass, as against the meeting of high spots, with the consequent breaking down of the wheel. In point of fact, better progress is made by adopting four or five cuts of small depth on a bar than three or four heavier ones. The grinding-wheel must be of suitable grit and grade for the material and size of work being ground, and must be kept true and bear " flat on " to the work to ensure good finish.

The problem of keeping truth in the grinding-wheel is much more exacting in this type of grinding than in ordinary cylindrical grinding. In the latter the work is reciprocated in its relation to the wheel, thus breaking down the tooth of the wheel uniformly from each side. In the continuous centreless method the work is being presented to the wheel continuously from the same side, thus tending to glaze and load up the wheel sooner than by the cylindrical method. This is an additional reason for not forcing the cut. The usual coolants are used, it being essential to keep a copious flow.

The work in passing the grinding-wheel is controlled by a suitable stay. These are of various types, in some cases consisting of a block with a half-round groove in line with the axis of the bar, and in which the bar revolves, being kept up by the action of the wheel, and in other cases by a three-pin type of steady. The latter is preferable for varying diameters, and possibly does more accurate work whilst taking less upkeep. Circular and longitudinal motion is imparted to the bar by means of two fixed heads, one at either end of the machine. These heads comprise a suitable type roller-feed mechanism, or alternatively a plate-friction drive mechanism. The former is more positive, and is essential for working from the black, whilst the latter is more suitable for small sizes of drawn material. The commercial sizes produced range from $\frac{1}{16}$ in. to $1\frac{3}{4}$ in. diameter, beyond which difficulties of straightness and stiffness of the bars become troublesome. It will be seen, therefore, that whilst the limitation of the short method is principally length, the limitation of the rod-grinding process up to the nominal is diameter. Thus, each have their limitations, but both provide great facilities for work suitable to them.

In regard to production, with the short type of machine production figures can only be arrived at by a study of the particular job, as in most other types of machine, but in the rod-grinding it is merely a matter of diameter and length, and figures are much more reliable. It is, however, a fact that in the production of details of a plain nature, although short, such as a mild-steel pin or shaft, say, 4 in. long, it is much more expeditious to grind the bar in long lengths and afterwards cut it up, than to cut it up firstly and then grind in the short machines, and this in spite of any magazine feed which may be used on the latter, always given that the amount of material to be removed is the same in both cases. Over a quantity the details produced from the ground bar will be found to be more accurate. It is,

of course, impossible to use this method on details which have to be hardened, and in such case the short type of machine is essential.

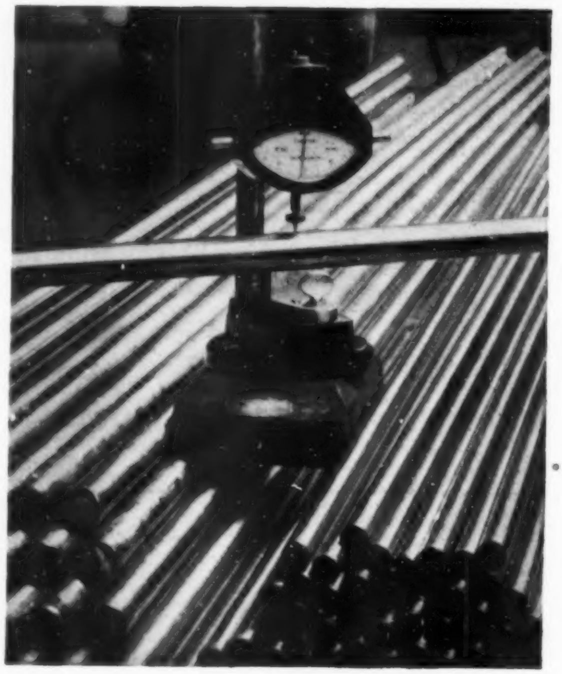
Examples of times taken on the rod-grinders for removing 4/6 thousandths and finishing to limits of plus or minus 0·00025 in. over a run of work are—

$\frac{1}{4}$ in. dia., 168 ft. per hour.
1 in. dia., 21 ft. per hour.

The uses of centreless ground work produced on the short machines are apparent. These machines provide an expeditious, economical method of dealing in an accurate way with countless details of varied form and design, which it would be commercially impossible to deal with by any other means, and it may be said that the introduction of this type of grinding marks one of the greatest forward steps in machine-shop practice.

The use of precision ground bar and rod is not quite so apparent, but is, nevertheless, equally important. In the beginning black bar was universally used, together with the turner's art. Then followed bright-drawn bar, an admirable product in its sphere, and affording facilities over black bar unheard of until its advent. Then came the age of accuracy with repetition production, and although the bright-drawn product possessed a certain degree of accuracy, it was found to be inaccurate enough to upset most estimates of production, where production of finished assemblies had to be guaranteed at so many per week. Thus, the precision-ground bar not only is accurate in itself, and that to a surprising degree, but forms the true basis for all estimates of production in a given time, as it obviates all loss of time due to shafts being slightly tight and needing easing, or slightly easy and calling for a judicious selection.

The value of this feature cannot be expressed in price per foot, but is apparent to the keen student of production, who must be certain of a regular given output against inflexible standing charges. This view has become recognised, and there are in this country a few firms who produce this material, and at least one who devote themselves exclusively to it. Amongst the numerous new activities of the present day, this development, although not so much heard of as many others, is certainly proving its value, and gaining for itself a place in the special processes for which this island is famous, and in which it still leads.



Accuracy on bars ground by the long process is shown to be within $\frac{1}{10000}$

ACID RESISTING STEEL.

(*Continued from page 20.*)

which has been achieved during the last decade in the production of steels as regards their ability to resist the strongest of corroding media, and, in the second place, to emphasise how very essential it is that in studying the effect of any particular medium the experiments should be made to include the whole range of concentration and temperature. A steel may successfully or sufficiently resist a particular corroding medium of a particular concentration, and, say, at the ordinary temperature, but even when it is thought that great success has been achieved disappointment will ensue unless the experimental work is designed on the somewhat broad lines indicated in these experiments.

Whilst this article has been confined to the action of four particular acids, which are, of course, known to be amongst the most active corroding agents, yet it will be appreciated that the modifications in composition, which have changed the response in these particular instances, have also resulted in providing materials capable of resisting a very large range of corroding influences. The best that can be hoped for in the development of this subject is to extend the range of resistance, and it must be conceded that alloy steels are now available which adequately deal, not only with normal conditions that induce corrosion in ordinary ferrous materials, but which are now available for many particular purposes where active chemical agents have to be combated. The subject is a very large one, but to review effectively the resistance obtained by still further modifying the composition of the steels is beyond the possibility of the space now available.

ELECTRIC WELDING APPLIED TO BRIDGES AND OTHER STRUCTURES.

The system of welding employed on the London and North-Eastern Railway is that known as the quasi-arc, in which the structure to be strengthened or repaired constituted the negative pole of the circuit, and the metal, called the "electrode," formed the positive pole. On contact being established between the electrode and the work an arc is formed which fuses the electrode, and metal flows from the electrode and adheres to the work. It appeared that though the poles might be reversed, or an alternating current used, the metal would still flow from the "electrode" to the work, and not vice versa. The most suitable voltage was between 30 and 60, and the current 100–105 amps. per welder. In order to test the strength and cost of the welding system, Mr. H. Bruff and the Bridge Engineers Department of the Northern section of the railway carried out a number of experiments. A steel beam was cut in halves, one half left untouched, and the other had its tension flange cut through, and it was otherwise completely ruined, in which state it was handed to the electric welders for repair. Subsequent tests on the untouched half and the repaired half proved the latter to be stronger than the original beam.

The success which had been achieved on old works had led the L.N.E.R. to employ the method in the fabrication of new steel structures with equally good results, and the principle had also been applied to the building-up of worn points and rails at crossovers with much success.

Elaborate tests had been made by the company and at Armstrong College, Newcastle, to determine the relative tensile strengths of joints made by riveting and welding, nearly all of which indicated the superiority of the latter, provided the work was done by a careful operator using an electrode of the appropriate size and quality.

Non-Ferrous Metallurgy.
Can it be Revived in Great Britain ?

By WM. CULLEN, L.L.D., M.INST.M.M., M.I.CHEM.E.

Stocktaking of British Resources shows they are satisfactory enough to justify increase in Non-Ferrous Metallurgy

THE reasons for the decadence of non-ferrous metallurgy in Great Britain are well known, but until the end of last century the position was not nearly so unsatisfactory as it is to-day. Swansea and other centres formerly received complex ores from all over the world, apart from domestic ore. To-day there are practically no domestic ores, and complex ores have ceased to come. True, a small quantity of lead ore (*galena*) is still produced, but most of it apparently is sold to continental purchasers. Zinc and copper are in much the same position, but there is just a slight prospect of all three reviving to an appreciable extent, as some recent mining developments look encouraging. Moreover, geophysical methods rather indicate the possibility of fairly large deposits in this old-worked country.

The position of nickel, aluminium, and tin forms a much more cheerful picture. Nickel, through the Mond Nickel Company, has relieved a little of the gloom which has fallen upon Swansea, and the large oil refinery of the Anglo-Persian Oil Company in the neighbourhood has been helpful. Aluminium is also fairly satisfactory, the production for 1927 having been about 9,000 tons. Tin mining shows little progress on account of the depressed price of the metal, but Cornwall has still very large reserves of lode tin which will come into its own through time. The smelting of tin is as satisfactory as can be expected, but increases can hardly be looked for in the immediate future.

INTERNATIONAL STOCKTAKING.

Practically all countries of the world have, within recent years, taken stock of their position with regard to basic metals and minerals, and even the United States, which is probably better endowed by nature than any other country, has recognised through the *Leuth Committee that it must still import quite a considerable range of essential minerals. One of its conclusions is worth putting on record here, viz. :—

> "Minerals should be concentrated, smelted, or fabricated near the source of the supply with limitations." (Resolution 3, p. 16.)

As a general resolution this is quite unexceptional, but as the last two words indicate, it is not of universal application.

The zinc industry of Belgium, which is now so closely interlocked with many other industries of that country, shows this very clearly, and an exact parallel is to be found in the oil-refining industry of this country. Theoretically, oil should all be refined near to its source, but even in America crude oil has often to be transported thousands of miles before it reaches the refinery.

EMPIRE MINERAL RESOURCES SHOW SURPLUS.

Europe as a whole, apart from Russia, is not very well endowed with mineral resources, and though some countries are better off than others—Spain for instance—no single one, and indeed no contiguous group, is self-sufficing. And yet within the British Empire itself there are sufficient metals and minerals, not only for its own requirements, but, in most cases, to provide a surplus for export. True, that surplus may reach other countries, Belgium, for instance, in the form of concentrates, but Great Britain to-day is far too dependent on other countries for its essential requirements, and the author's plea, made in a paper he read before the Institution of Mining and Metallurgy, is that it should, within the confines of the United Kingdom, do more of the necessary refining and fabricating of minerals than it does to-day. Other countries in Europe are naturally in much the same position, but Germany in particular is making heroic efforts to make itself more independent in respect of certain metals—an altogether laudable project.

At this stage it might be well to quote a few figures of production and consumption for the year 1926, which was, unfortunately, the year of the General Strike in Great Britain.

Copper.—World's production, 1,510,000 long tons, of which U.S.A. produced 55%, British Empire 3·8%, Germany 3·7%, Great Britain 1·1%. Germany has some copper ore, but has also to import. The British production practically all comes from pyrites cinders. Consumption in the United Kingdom, 120,000 to 140,000 tons.

Lead.—World's production, 1,620,000 long tons, of which U.S.A. produced 41% and British Empire 20·5% = 332,000 tons. Great Britain only produced 4,266 tons, Germany 88,637 tons, and Belgium, which has no lead ores, 86,500. Consumption in United Kingdom, 220,000—250,000 tons.

Zinc.—World's production, 1,210,000 long tons, of which U.S.A. produced 46%, British Empire 10% (120,000 tons), Poland 10%, Belgium 15·5%, Germany 6%, France 6%. (Note.—The United Kingdom produced only 17,000 tons in 1926, which was increased to 42,000 tons in 1927.) Consumption in United Kingdom, 160,000—180,000 tons.

Manganese Ore.—World's production of washed ore, 3,100,000 long tons, of which British Empire produced 45%. An indication of the production of ferro-manganese and spiegel-eisen by the following countries can be found in their importation of ore :—

	Tons.
Great Britain	142,605
Belgium	264,320
France	601,853
Germany	195,914
Norway	133,728
U.S.A.	347,378

Great Britain and Norway export considerable quantities of ferro-manganese.

Vanadium.—Probable world's production 750 short tons, of which U.S.A. is responsible for 500 tons, the balance being divided between Germany, England, and France. America uses three times as much vanadium per ton of steel as the rest of the world.

Chromium Ore.—World's production, 360,000 long tons, of which British Empire produced 58% (Rhodesia 44·7%) ; U.S.A. imported 215,464 tons from various countries. The major quantity goes to the making of ferro-chrome, chromate, and bichromate manufacture only accounting for a small proportion of the total.

*The International Control of Minerals, New York, 1925.

COPPER SMELTING.

The case of copper might, with advantage, be pursued a little further, and the question may well be asked, why is there so little copper smelting and why is there no electrolytic refining in the United Kingdom? The Empire's production of copper ore in 1926 was equal to 97,000 tons metal = 6·4% of the world's total, whereas the actual copper produced was 74,453 tons = 4·9%, made up as follows :—

	Tons.
United Kingdom	17,700
Northern Rhodesia	708
Southern Rhodesia	7
South Africa	8,681
Canada	30,239
Australia	11,148
India	5,800
Papua	170
	74,453

Much of this requires no refining at all, and the Canadian production is refined either in Canada—the right place, as power there is cheap—or in the United States, where there is great experience, and consequently great efficiency. It is perfectly evident, therefore, that, even taking the broadest view, the present Empire production of ore and of copper is not great, and has not been great for many years. There is hardly sufficient Empire copper available to feed an electrolytic refinery or even a smelting works of moderate size, though Germany, which is nearly as badly situated as ourselves with regard to ore supplies, has at least two of the former and several of the latter.

FUTURE PROSPECTS.

But the future holds much brighter prospects, for undoubtedly two of the greatest copper deposits of the world, now being exploited, are situated within the Empire, in Canada and Northern Rhodesia respectively. The Canadian copper will be refined in Canada itself. This is definitely decided upon, and the sites for the new works have been located. It will be some years yet before the output of Northern Rhodesia will reach substantial figures, but the author holds the view that unless the Transvaal, with its cheap coal and consequential cheap power, or the Victoria Falls, with the possibility of cheap hydro-electrolytic power, step in, the Rhodesian copper can be as cheaply refined in the United Kingdom as anywhere else in the world, not excepting the U.S.A.

In this connection, Lord Weir, an experienced and sagacious industrialist, writing to the London *Times* on January 1 last, after a trip to the U.S.A., says :—

> "My main conclusion, expressed broadly and simply, is that I can see no fundamental obstacle, either economic, social, or political, to prevent us from reducing the unemployment figures very substantially in the next three years, provided we bestir ourselves to the task. Equally broadly, this conclusion is based on a fixed conviction that this Great Britain of ours is the best and most effective location in the entire industrial world for the efficient production of many basic products. A study of our imports shows quite clearly the field for ample additional employment for our people, and to translate this into reality only requires confidence, organisation, executive capacity, and capital.
>
> "There are few things being produced in the United States which we could not produce at least as economically and as efficiently, provided we organise ourselves to do it, and I was much struck by the open secret that the most far-sighted, acute, and intelligent industrial leaders in the United States are entirely convinced of the tremendous advantages of manufacturing in Great Britain.
>
> "An analysis of United States cost of production seems to me to prove conclusively that, with similar production facilities and methods, with British geographical freight advantages, with British labour even at remuneration in excess of existing rates, British costs can be economic and command the world's markets. To enable the relative scale of production to be sufficient to realise these results, no new market need be searched for, as it exists in the form of our own imports. We are paying foreigners to do work on which our own people should be effectively employed. All that is required is a new spirit of enterprise, confidence, and capital."

Lord Weir mentions unemployment, and it is this very serious problem which directed the author's thoughts to this subject. Unless, however, economic and other conditions are satisfactory, it is obviously useless to pursue this particular project any further. These questions turn on—

(*a*) Political stability and labour.
(*b*) Cheap and good transportation.
(*c*) Cheap fuel and power.
(*d*) Technical experience.
(*e*) Finance.
(*f*) Local and Imperial taxation.

It is impossible to go into these fully here, but the author is satisfied that on the whole they are satisfactory enough to justify a large increase in non-ferrous metallurgy. True, our labour (*a*) is more expensive than that of most European countries, but it is only about 40% that of the U.S.A. Our transportation (*b*) is also expensive, but that can be neutralised by choosing coastal sites. Fuel and power will be referred to presently, but in (*d*) technical experience, we are decidedly weak. Finance (*e*) need present no difficulties, but with regard to (*f*) we are undoubtedly the highest taxed nation in the world, though recent legislation has given a considerable amount of relief to productive enterprises so far as local taxation is concerned.

CHEAP POWER NEEDED.

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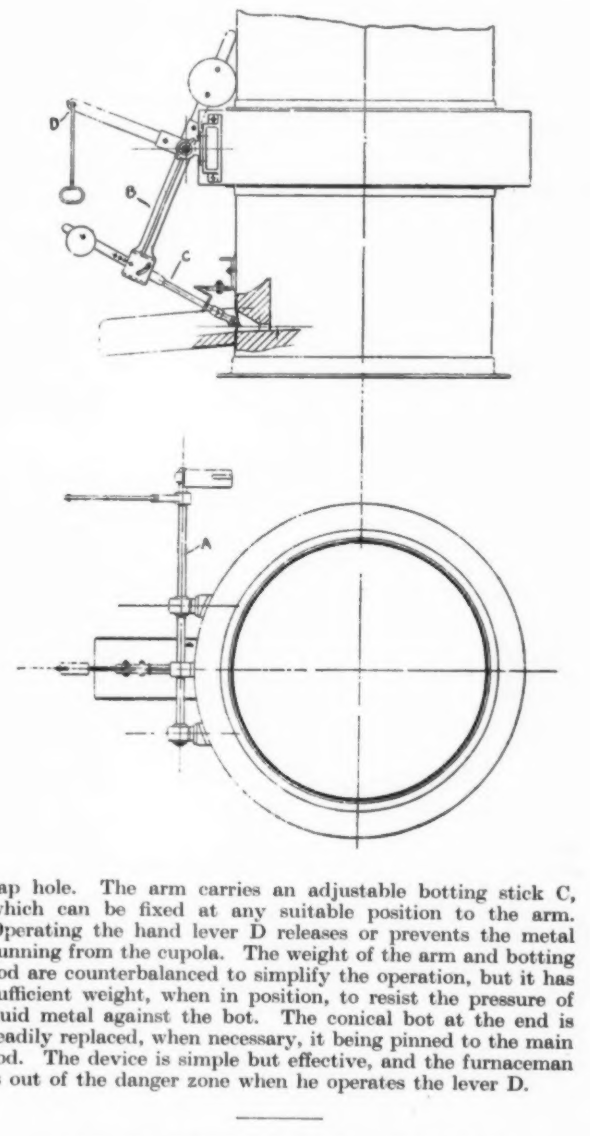

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COPPER SMELTING.

The case of copper might, with advantage, be pursued a little further, and the question may well be asked, why is there so little copper smelting and why is there no electrolytic refining in the United Kingdom? The Empire's production of copper ore in 1926 was equal to 97,000 tons metal = 6·4% of the world's total, whereas the actual copper produced was 74,453 tons = 4·9%, made up as follows :—

	Tons.
United Kingdom	17,700
Northern Rhodesia	708
Southern Rhodesia	7
South Africa	8,681
Canada	30,239
Australia	11,148
India	5,800
Papua	170
	74,453

Much of this requires no refining at all, and the Canadian production is refined either in Canada—the right place, as power there is cheap—or in the United States, where there is great experience, and consequently great efficiency. It is perfectly evident, therefore, that, even taking the broadest view, the present Empire production of ore and of copper is not great, and has not been great for many years. There is hardly sufficient Empire copper available to feed an electrolytic refinery or even a smelting works of moderate size, though Germany, which is nearly as badly situated as ourselves with regard to ore supplies, has at least two of the former and several of the latter.

FUTURE PROSPECTS.

But the future holds much brighter prospects, for undoubtedly two of the greatest copper deposits of the world, now being exploited, are situated within the Empire, in Canada and Northern Rhodesia respectively. The Canadian copper will be refined in Canada itself. This is definitely decided upon, and the sites for the new works have been located. It will be some years yet before the output of Northern Rhodesia will reach substantial figures, but the author holds the view that unless the Transvaal, with its cheap coal and consequential cheap power, or the Victoria Falls, with the possibility of cheap hydro-electrolytic power, step in, the Rhodesian copper can be as cheaply refined in the United Kingdom as anywhere else in the world, not excepting the U.S.A.

In this connection, Lord Weir, an experienced and sagacious industrialist, writing to the London *Times* on January 1 last, after a trip to the U.S.A., says :—

"My main conclusion, expressed broadly and simply, is that I can see no fundamental obstacle, either economic, social, or political, to prevent us from reducing the unemployment figures very substantially in the next three years, provided we bestir ourselves to the task. Equally broadly, this conclusion is based on a fixed conviction that this Great Britain of ours is the best and most effective location in the entire industrial world for the efficient production of many basic products. A study of our imports shows quite clearly the field for ample additional employment for our people, and to translate this into reality only requires confidence, organisation, executive capacity, and capital.

"There are few things being produced in the United States which we could not produce at least as economically and as efficiently, provided we organise ourselves to do it, and I was much struck by the open secret that the most far-sighted, acute, and intelligent industrial leaders in the United States are entirely convinced of the tremendous advantages of manufacturing in Great Britain.

"An analysis of United States cost of production seems to me to prove conclusively that, with similar production facilities and methods, with British geographical freight advantages, with British labour even at remuneration in excess of existing rates, British costs can be economic and command the world's markets. To enable the relative scale of production to be sufficient to realise these results, no new market need be searched for, as it exists in the form of our own imports. We are paying foreigners to do work on which our own people should be effectively employed. All that is required is a new spirit of enterprise, confidence, and capital."

Lord Weir mentions unemployment, and it is this very serious problem which directed the author's thoughts to this subject. Unless, however, economic and other conditions are satisfactory, it is obviously useless to pursue this particular project any further. These questions turn on—

(*a*) Political stability and labour.
(*b*) Cheap and good transportation.
(*c*) Cheap fuel and power.
(*d*) Technical experience.
(*e*) Finance.
(*f*) Local and Imperial taxation.

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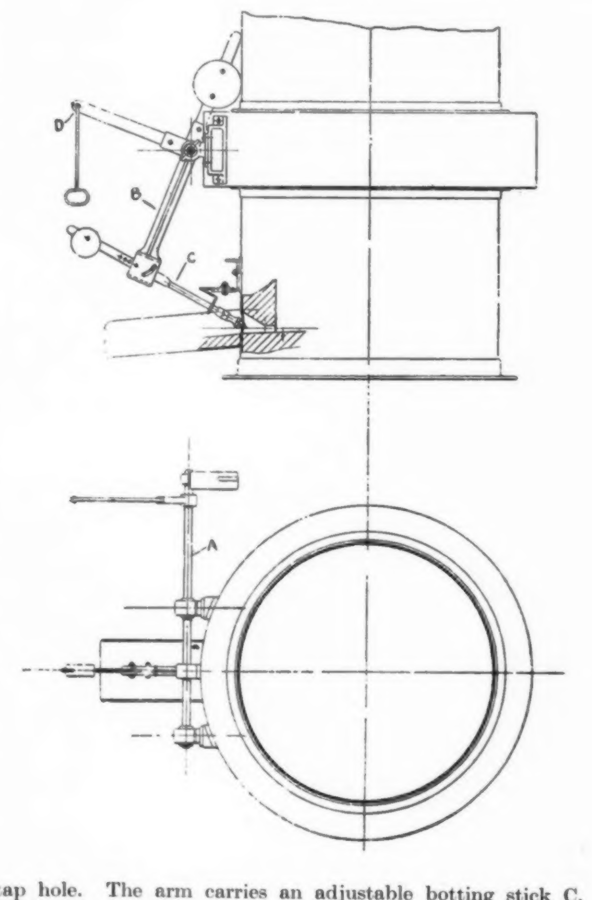

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Principles and Uses of Wire Rope

PART I.

By WALTER A. SCOBLE, D.Sc., M.I.Mech.E.

Head of Engineering Department, Woolwich Polytechnic.

First of a Series of Articles by Dr. Scoble, who is a member of the Wire Rope Research Committee.

THE importance of an understanding of the principles which govern the manufacture and use of wire ropes follows from the widespread use of such ropes by engineers engaged in all branches of the profession. Most cranes employ wire ropes to lift the load, and many require ropes to manœuvre the crane. Wire cables are used also for lifts or elevators, for winding and haulage in mines, for aerial ropeways, well-boring, towing and mooring of ships, and a variety of similar purposes.

The treatment of the rope in the services enumerated above may be divided into two divisions. In the first, the rope moves, and in moving passes over pulleys, and often is alternately wound on and uncoiled from a drum. The second group includes those cases in which a cable is subjected to varying tensions, probably in the nature of shocks, sometimes superimposed on a steady tension. Examples of the first division are the working ropes for cranes, lifts, winding, haulage, and well-boring, whereas towing cables have been quoted to represent the other section. The distinction drawn is useful to facilitate the study of the destructive influences which promote failure of a rope, but the conditions which have been taken as a basis for the division can operate simultaneously, bending of the rope over pulleys and drums and a rope tension which varies from time to time, the most important example of which is the case of the winding rope for a mine.

Wire rope is such a useful commodity that its uses are continually expanding and cannot be adequately enumerated here, but another important class of ropes must be noted and will be called "standing rigging." Such ropes are used merely as tension members in a structure, such as stays on a ship or for a crane post, and in a higher quality for aircraft bracing.

STRENGTH AND FLEXIBILITY.

The advantages which have led to the extensive use of wire rope are the results of either or both of its two important properties—namely, its strength and flexibility. The wire will be discussed more fully later, but at this stage it must be realised that the steel is strengthened by the cold work done on it during wire-drawing, and in consequence the tensile strength of the wire is much higher than that of the steel from which it is drawn. An average strength for engineering ropes is of the order of 100 tons per sq. in., but for aircraft this is increased to about 150 tons per sq. in. The high strength of wire permits the manufacture of rope for which the ratio of the strength to the weight per foot is much lower than that for a single steel rod.

The flexibility of wire rope is often beneficial, whereas it is essential for many purposes. It is unfortunate that the term flexibility is used to indicate different properties which, however, are related to each other. A rope may be required to bend readily—that is, by the application of a small bending moment,—or it may be necessary to bend a rope in an arc of small radius without overstressing the wires. The former is a condition for easy handling, but the second again leads to a sub-division.

It cannot be emphasised too strongly that an unusually large number of variables appear in connection with both the construction and the use of ropes, and cases are frequently met with in which the neglect or misunderstanding of the influence of one of these factors has caused poor rope service. Often a cure is attempted by making alterations which are entirely unwarranted and are misleading and futile.

MOVING OVER PULLEYS.

Returning to the subdivision indicated: Firstly, if a rope is bent to a small radius, with the result that the wires are overstressed, they take a set, and the rope is kinked. The kink weakens the rope, and its subsequent handling is made more difficult. The second case arises when the rope is bent repeatedly to a small radius, and an example of this treatment is a crane rope which is worked over a pulley of insufficient diameter. The wire is given a set the first time it goes over the pulley, tends to straighten after the pulley is passed, and the cycle is repeated each time the rope meets the pulley. Ropes are commonly employed in this way, although the wire is damaged from the first use of the rope, which must break after comparatively few such severe bends.

The subject of flexibility may be considered by means of the formulæ used in connection with bending—namely, $f/y = E/R = M/I$, in which f is the stress in the material at a distance y from the neutral axis; E the modulus of elasticity of the steel; R the radius of curvature if the bending is from the straight; M the bending moment applied; and I the second moment of area of the section about its neutral line, which for a circle is $\pi d^4/64$.

The conditions to be met to permit a rope to be easily bent in relation to its size can be deduced from $E/R = M/I$, or $M = EI/R$. E is taken here as the tensile modulus of the steel, and so is practically constant. When different specimens of rope are compared, each may be considered to be bent from the straight to the same radius R. E and R being constant, it follows that the moment necessary to bend a wire is proportional to I—that is, to the fourth power of the wire diameter, d^4. But if the ropes have equal sectional areas, since the section of each wire is proportional to d^2, the number of wires which must be bent in a rope varies as $1/d^2$, and the moment to bend the rope is proportional to $d^4 \times 1/d^2 = d^2$. The simplest way to express the conclusion seems to be, that for ropes having the same breaking strength and made of the same tensile wire the flexibility referred to now, which is the converse of the moment necessary to bend the rope, is proportional to the number of wires used for the construction. It is assumed, for simplicity, that all the wires in the rope are of the same diameter. The problem is complicated when wires of different diameters are used, and by certain other modifications, but the general conclusion remains, that a rope is more flexible when it is composed of a larger number of smaller wires.

The stage at which a rope is damaged is indicated by $f/y = E/R$. The greatest stress is located at the outside of the wire, where $y = d/2$. R, the radius of curvature of the rope, is D/2 when the rope is bent over a pulley or drum of diameter D. This leads to a more useful formula for the present purpose, $f = Ed/D$; d and D being the wire and pulley diameters respectively. It must be remembered that these formulæ are true only within the elastic limit of the material. When the formula is used, and the calculated value of the stress exceeds the yield stress of the steel—say, 80% of the strength of the wire,—

this means that the value found would be the stress if the wire were still wholly elastic. Actually, the elastic limit is exceeded at the outside of the wire, and the metal yields and is permanently damaged. The amount by which the calculated value exceeds the elastic strength of the steel indicates the extent of the yielding, and the consequent damage done to the wire.

When the flexibilities of ropes are compared in the present sense, E and D are constant, and the stress in the wire caused by bending is proportional to the wire diameter, or the flexibility varies as $1/d$.

MANUFACTURE OF WIRE ROPE.

So far it has been shown that if a tension member is made of a number of wires, it can be made of less weight for a given strength than a single bar, with the additional advantage that the moment required for bending is reduced and the stress caused by bending is also reduced, but not to such a great extent. Already theory has crept into the introduction before the manufacture of wire and rope has been dealt with, so these parts of the subject will be treated next.

The wire used for ropes opens up so many complex and controversial questions that it is difficult to treat the subject in an orderly fashion, but those who are specially interested should consult "Wire Drawing and the Cold Working of Metals," by Alastair T. Adam, a book which gives many references at the ends of the chapters. The first complication arises because, in general, wire rope is manufactured in stages in several works. A steel manufacturer supplies an ingot to a rod-mill which converts the steel into wire rods of from ¾ in. to ¼ in. diameter. The rod is coiled for transport, and is the raw material of the wire-drawer. Finally, the wire is sent to another works to be laid into rope. Difficulties appear because defects in the original ingot are of necessity carried through to the wire and the rope, which indicates that it is desirable that the wire-drawer should produce his own steel. It has often been said that good steel can be spoilt, but good wire cannot be made from bad steel. The steel-maker may use poor raw material, or the steel-maker or rod-roller, or wire-drawer may spoil good steel, yet the rope manufacturer must rely on each of these who carries out an operation in the manufacture of finished wire.

The steel used for the production of wire is defined by three grades in descending order of quality—namely, special acid, acid, and basic. It does not appear to be necessary to deal here with the differences in the raw material for, and the method of manufacture of, acid and basic steel. When the failure of a rope may endanger human life the use of acid steel is compulsory, but in all other cases either quality of steel may be specified. Wire-drawers claim to draw basic wire from good basic steel equal in quality to acid wire; but all basic steel is by no means good. There is other evidence which probably influences engineers to insist on acid wire for important rope service. It is generally agreed that basic steel is unsuitable for the production of wire either of very small size or of the highest tensile strengths. Consequently, when rope breakage may cause injury or loss of life to workpeople, as with crane, lift, and winding ropes, acid steel, which is not so likely to be of poor quality, is used in preference to basic steel, which is known to have limitations even for the best material. The first British Engineering Standards Specifications implied that the material for special acid was of a higher quality than that for acid steel, because the test requirements were precisely the same for both. It appeared to be suggested that greater care in the selection of the raw material and in the process of manufacture gave the special acid steel a superiority which led to better service, although it was not shown by the test results. The percentages of sulphur and phosphorus were each limited to 0·04% for both special acid and acid steel. This figure now applies to special acid, and the maximum percentage allowed for acid is 0·05, so that these two grades are distinct to some extent.

THE EFFECT OF DEFECTS IN THE STEEL.

The steel is cast into an ingot, and, even when the raw material is satisfactory, bad casting causes defects which persist through all the subsequent processes, and appear in the finished wire. One such defect in the ingot is surface flaws, noted by Adam, which is not so evident to the rope user, but which causes much trouble to the wire-drawer. It must also be realised that the steel ingot is rolled and drawn down to a smaller diameter, with a corresponding increase in length. The wire which results is required to be of uniform composition and structure to give the same strength and properties at every point, but if the steel ingot is of uneven composition the wire will vary similarly along its length. So the main points to be observed during the casting of the steel ingot are the avoidance of structural defects, and to ensure that the steel is homogeneous—that is, to avoid segregation. This is not entirely possible, so segregation should be confined to the top portion of the ingot, which is cropped off with the piping.

At this point it is desirable to emphasise two points related to the above, which may escape notice. A small structural defect in the steel, which may be unimportant in a bar of large section, will cause serious weakening of a wire. Also, specifications limit the amount of sulphur and phosphorus in steel, but, as Adam has explained, the percentages of these impurities should be controlled at any point in the wire rather than that the average amount should be limited, consequently segregation may defeat the specification. It is also clear that an uneven distribution of carbon along a wire must lead to variable strength and ductility.

High sulphur and phosphorus in steel wire lead to flaws and poor surface finish, promote corrosion, and prevent satisfactory galvanising.

"PATENTING" AND DRAWING OPERATIONS.

The steel is hot-rolled into coils of wire rod, which are usually of 5 S.W.G.—that is, of 0·212 in. diameter. The rods are cold-drawn in the wire mill, when the resulting wire is made of truly circular section and its tensile strength is increased. Larger rod than 5 S.W.G. is used only when this is essential to allow enough cold-drawing, in bringing down to the final size, to increase the tensile strength of the wire to that required.

The steel for roping wire contains from 0·5 to 0·8% of carbon, and usually the rods have to be heat-treated before the drawing operations. This process is called "patenting," and is really a normalising. The rods are heated to about 1,000° C., and are cooled in air or molten lead, the steel being made more homogeneous with a fine pearlitic structure. When the temperature of the lead-bath is maintained between 400° and 550° C., its use leads to wire with superior mechanical properties to those of wire drawn from air-cooled rod. Adam refers to this matter in his book, and returns to it in a recent paper*, where he writes, "It is suggested that the best rope wire is made by selecting a steel of the lowest carbon content consistent with the tensile strength desired, making the greatest use of the carbon by lead quenching, and giving the wire a total reduction of area of between 50 and 80%, according to the diameter, carbon content, quality of steel, and reduction per pass; the better the quality of steel, the lower the carbon, and the easier the stages of reduction, the greater the total reduction may be.

The rods must be freed from the scale, and the only practical and efficient method of doing this is by pickling in acid, either hydrochloric or sulphuric. The scale is removed by the hydrogen generated by the action of the acid on the steel. Where the scale is thin the acid tends to attack the metal unduly before the thicker scale is removed. This is prevented by the addition of a colloidal restrainer, which forms a protective film on the surface of the metal after the scale is removed, and prevents further attack by the acid.

(*To be continued.*)

* "Engineering," September 1929.

ELECTRIC HEAT-TREATMENT OF METALS

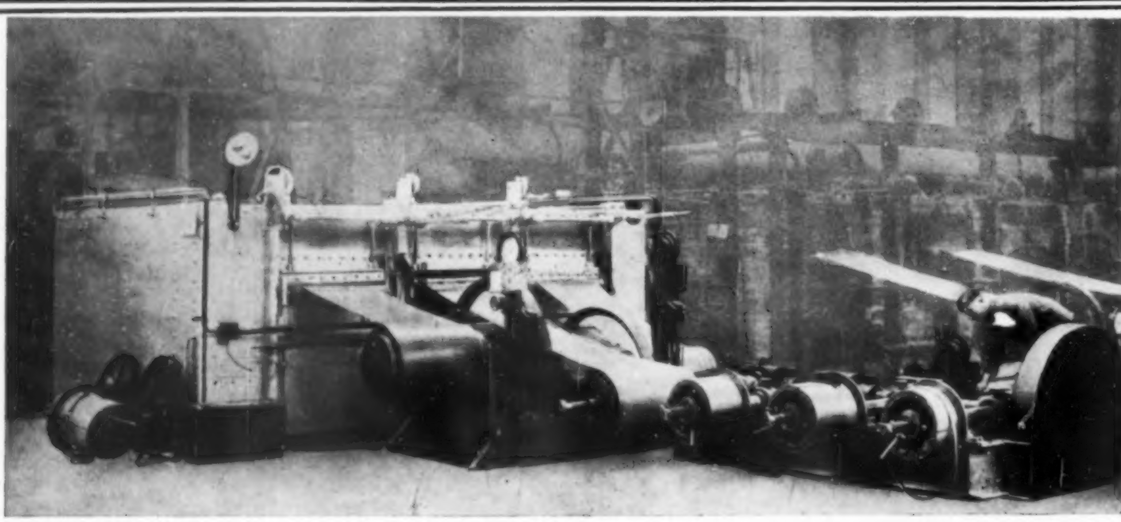


Fig. 4, Continuous Strip Furnace.

By

W. J. MILLAR and A. G. ROBIETTE, B.Sc.

(of Electric Furnace Co., Ltd.)

The authors have been associated with the development and application of electric furnaces in this country for many years, and, in view of the increased interest in industrial electric heating, their views have a special value.

THE industrial application of electric heating, though well established in both ferrous and non-ferrous melting practice, has not received the same attention from users in other fields, but it is now rapidly asserting itself in the domain of the heat-treatment of metals. The day is long past when science first entered the heat-treating shop. Old rule-of-thumb methods have been discarded, and the equilibrium diagram has become the ruling factor in the heat-treatment of metals. The operator must now work to certain fixed predetermined temperatures and time-temperature curves, and the need of a more controllable source of heat than the crude and capricious fuel-fired furnace has become glaringly apparent.

The electric furnace, which eliminates completely the human element, holds out at present the only true solution of the scientific heat-treatment of metals.

The radiant heat-resistance type of furnace was tardy in making its industrial appearance, but is now penetrating rapidly and surely on its merits into branches of industry of a widely varied description. The most salient features of electric heating, as applied to the heat-treatment of metals, lie in the accurate temperature control and uniformity of heat distribution, and it will be seen how imperative this is in many metallurgical operations.

Other features, fundamentally of relatively minor importance to the metallurgist but of consequence to the plant engineer, are the absence of waste products of combustion, the elimination of solid fuel and ashes, with their inherent problems of handling and removal, the entire absence of flues and foundations, and, to anyone who has been faced with the endless problems of modern shop layout, the advantage of being able to install electric furnace equipment just where it is wanted—viz., in the direct line of production.

For instance, where electric heating has not been adopted, it is necessary to construct the heat-treatment department in a position most accessible for the handling of fuel and the construction of flues and chimneys, necessitating heavy and sometimes inconvenient handling operations between the machine-shop and the heat-treatment department. Often it would be of infinitely great advantage to install the heat-treatment plant in the machine-shop, and this is what can be and is done with the electric furnace.

One particular example is in the heat-treatment of aluminium alloys, such as are used for motor-car pistons.

Taking, first of all, metallurgical considerations, the governing principle is to get as much of the intermetallic compound constituents ($CuAl_2$, Mg_2Si) into solid solution as possible before quenching. Since the subsequent age-hardness will increase with the amount of these compounds in solution prior to quenching, this means approaching dangerously near the solidus, as the solubility of these constituents increases rapidly with temperature. If the solidus temperature is exceeded, there will be incipient fusion of the material at the crystal boundaries, and the article will be fit for nothing short of remelting. With the electric furnace, where temperature limits can be controlled accurately throughout the volume of the heating chamber

to within plus or minus 5° C., it is impossible to overstep the solidus. The percentage of rejections is therefore reduced to zero, while the fullest possible advantage is taken of the ageing characteristics of the alloy.

A specially designed continuous conveyor type of electrically-heated furnace may be installed at the finishing end of the machine-shop, and the pistons, as they leave the inspection bench, charged directly upon the furnace conveyor. Conveyor speed and furnace rating are regulated so that the charge will be exactly at the quenching temperature of 480° to 510° C. by the time they reach the outgoing end,

a relatively small ratio to the total time, the overall running costs are much lower with electricity than with coal firing.

Thus, although using an expensive form of heat efficiently, the running costs are lower than when using a cheap form of heat wastefully. The reason is that fuel-fired furnaces require flues and chimney stacks to take away the waste products of combustion, and these at the same time account for a removal of a very high percentage of the potential number of heat units in the fuel. Heavy heat losses take place also through the walls of the furnace, through badly fitting doors, etc.

Top shows a specimen of Duralumin tempered at too high a temperature.

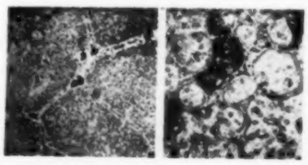
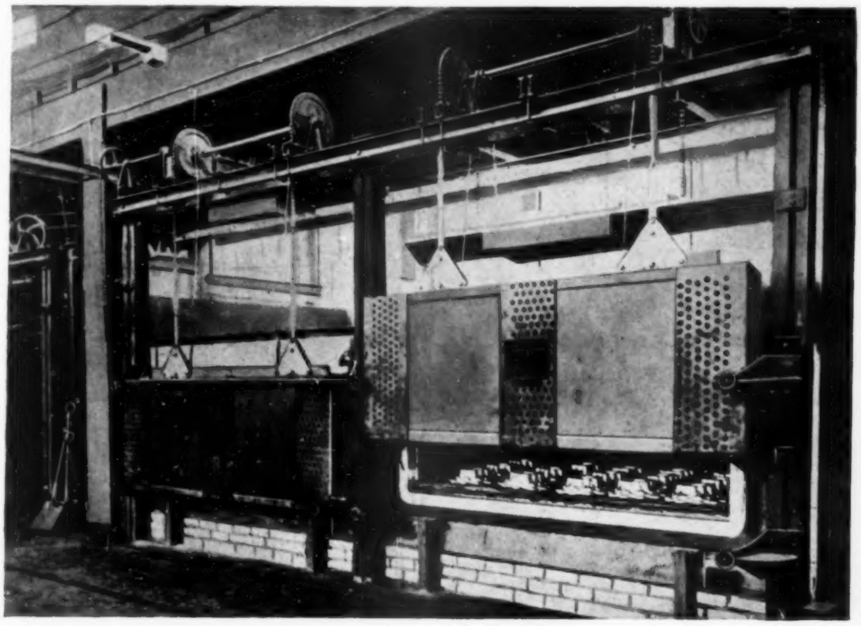
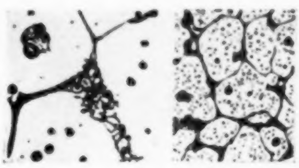


Fig. 1, on right, illustrates front view of Daimler furnaces.



Bottom is a result of overheating Duralumin showing incipient fusion at grain boundaries.



where they are automatically discharged into a water-quenching bath, which is maintained at a definite temperature. The subsequent tempering process is carried out by providing a second conveyor to carry the pistons through the quenching bath—where they are immersed for a definite interval of time,—or into a second electrically-heated chamber, and then on to the final receiving platform.

Electric heating is the most expensive form of heating which has been used industrially. In view of this fact, it might well be asked "Is electric heating worth while?" It is in very many cases, but due consideration must first be given before applying electric heating to any particular process.

In this country it would not be profitable to use electricity for reheating heavy steel ingots for rolling, or to malleableise heavy iron castings. Neither of these operations calls for extreme accuracy of temperature control, and the masses of dead work—in the form of heavy refractories—which have to be heated in the latter process render the working costs prohibitive. On the other hand, the age-hardening of aluminium alloys is one which can, with advantage, be carried out in the electric furnace in every case.

Fig. 1 illustrates a coal-fired furnace reconstructed for electrical heating, and designed for heat-treating aluminium alloy castings. It comprises two chambers, each measuring 7 ft. 6 in. × 8 ft. 6 in. × 2 ft. high, and the consumption per chamber required to maintain temperature during the soaking period, which may occupy from 18 to 40 hours, is 8 units per hour, or, with electricity at ¾d. per unit, 6d. per hour, which is only a small fraction of the cost of maintaining temperature with coal.

The initial heating may of course be more expensive when using electricity, but as the heating-up periods bear

The advent of electric heating has, therefore, introduced new problems of heat insulation to the furnace engineer, as it is essential that no avoidable heat units be allowed to escape from the furnace.

To be satisfactory, an electric furnace must be heavily lagged with heat-insulating material, must have doors carefully designed to obviate heat losses, and external charging equipment preferably provided, so that the door is opened for a minimum of time.

An example of a furnace embodying all these features is shown in Fig. 2.

The furnace is of the side-charging type, and is successfully used for annealing brass tubes. The door is motor-operated, and is provided with an automatic electric device to ensure its being tightly closed.

The overhead charging machine carries a charging platform with fingers narrowly spaced, to obviate sagging of the hot tubes. This machine charges and discharges the furnace, and plunges the tubes immediately they are withdrawn from the furnace into quenching and pickling-baths. The furnace has an effective working length of 23 ft., and is rated at 240 k.w. The output of one furnace working at 600° C. is one ton per hour, and the average power consumption is 127 units per ton.

Another recent design is that of a continuous billet-heating furnace. The furnace is of the double-ended type, so that as soon as the billet is removed from the end door for treatment in the rolling-mill or extrusion press, another is inserted in the front end, thus maintaining a constant reserve of billets to meet the exigencies of the rolling-mill.

(To be continued.)

GEAR AND METAL HARDENING.

A NEW method for hardening the wearing surfaces of gear-wheel teeth has been devised. It is known as the " Shorter " process.

The hardening is done by a special process machine in which a blowpipe and quenching pipe are mounted and directed on the surface to be treated. The operation is mechanical and under accurate control. The gear under treatment is mounted within a tank in definite relation to the traverse of the flame and cooling medium. Heating is effected by the cone of the burner as it passes over a tooth and a jet of water impinges upon the area of heated metal immediately after being heated. This quenching jet passes over the face of the tooth in a definite relation to the heating jet.

It must be distinctly understood that this is not a carburising process, the uniform hardness being obtained merely by heating and quenching, which changes the normal pearlitic structure of the steel in the heat zone to martinsite. The zone of treatment is illustrated in Fig. 1.

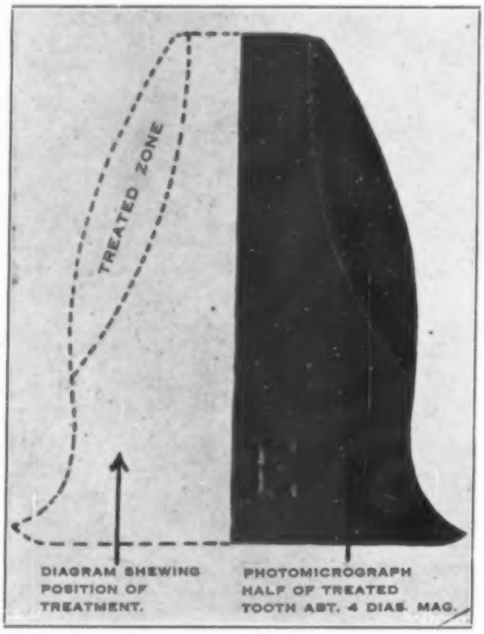


Fig. 1.—Zone of Treatment.

The depth of hardening produced is claimed to be considerably greater than is usually obtained by carburising. It is also claimed that distortion from this process is negligible, and within all reasonable limits for machined gear-wheels—a result due to the heat being applied locally, rendering the possibility of distortion infinitesimal. To prevent the heat affecting other parts, the tooth under treatment is immersed in water, and two or more teeth above it have a stream of cold water flowing over the faces.

The main part of the tooth is not affected by the process, and it is claimed that higher tensile steels can be used to give increased strength without detriment. Experiments have shown that a 0·45% to 0·55% carbon steel will produce a surface having over 600 Brinell hardness after being treated with this process. An interesting experiment recently made on a 1·2% carbon steel gave a Brinell hardness of 711 without surface cracks. The significance of this will be readily understood.

The quality of steel employed in the manufacture of the gear-wheels determines the quenching medium to be used with the process. Water is considered to be the most suitable medium for the plain carbon steels, but for special steels, nitrogen, or even air-quenching, may be desirable.

The machine as designed for the " Shorter " process will take gears of varying size, or it may be arranged to take special size gears only. The gear is readily mounted on an adjustable spindle and placed in bearings so arranged in the tank that the wheel may be wholly or partially immersed in the water, as required, during the time of treatment. The blowpipe supplying the heating medium is mounted upon a movable carriage, together with a number of suitably arranged water-pipes, as in Fig. 2, so that the whole may be traversed mechanically, accommodating to the operation. Special arrangements are made for dealing with worm and other gears, but the principle of the treatment is exactly the same.

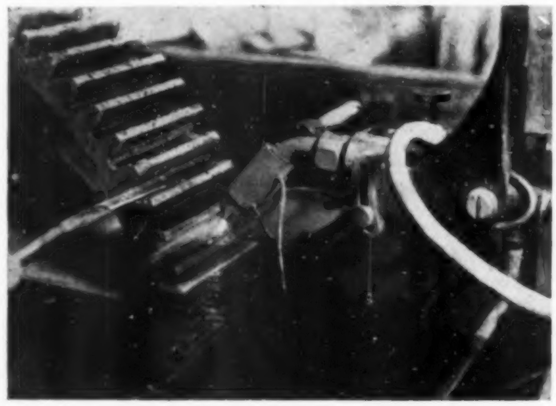


Fig. 2.—Arrangement for Hardening Gears.

In addition to gear hardening, the " Shorter " process has a wide application to cylindrical articles, such as spindles, clutch and brake drum frictional faces, an important development for the motor industry. It has also been applied successfully to worm-shafts, both large and small, without distortion. The process is patented, and is being developed by the Patent Gear and Metal Hardening Co., Ltd.

BUILDING UP WORN PARTS WITH METAL.

Worn machine parts—such as gears, shafts, splines, journals, and cams—can be built up with solid metal to their previous proportions with the aid of a metallising process recently developed by Metallisation (Sales), Ltd. The worn parts are subjected to a special treatment, from which it is claimed that the deposited metal grows outwards from the crystal surfaces of the underlying metal. This means that the adhesion between the deposited metal and the metal base is equal to that between the actual crystals of the metal itself. The metal used for building up the parts is generally nickel, which presents a surface hard enough to give long resistance to wear, but, at the same time, it is claimed that it can be machined or ground successfully, and there is no danger of peeling, flaking, or cracking, and deposits can be applied from one-thousandth to one-eighth of an inch in thickness.

WELDING HANDBOOK.

The progressive operator who is desirous of becoming better acquainted with the latest developments in metallic arc welding will find much valuable information in an operators' handbook recently issued by the Alloy Welding Processes, Ltd. It has been assumed that the operator has previously acquired knowledge in some particular phase of engineering practice, but highly technical phrases have been omitted. A careful perusal of this handbook will assist those who use discrimination to obtain better results, which may justify extended application of the process.

Russia as a Market for British Goods
Trade Possibilities

By An Observer.

Considerable interest in the Russian market has been aroused by the recent visit of a British trade delegation to that country (of which the writer was a member), and by the decision of the present Government to take what steps might be advisable towards a resumption of diplomatic and trade relations with that federation of Socialist Soviet Republics which we know as Russia, but which they themselves prefer to describe as U.S.S.R. This makes it imperative that reliable and unbiassed information on the subject should be in the possession of those business men who contemplate or have contemplated opening up trade negotiations. This it is the purpose of this article to give.

In considering Russia as a potential market, two points demand attention. In the first place, the subject cannot be considered as an indivisible entity. Secondly, there is, from the marketing point of view, a considerable difference between (1) Russia in relation to Great Britain at this moment—*i.e.*, with neither diplomatic nor trade relations; (2) Russia diplomatically and commercially in touch with Great Britain; (3) Russia in five years time.

Taking No. 1 first, it is fairly safe to say that *normal* trade relations are impossible in such circumstances. The situation is that ever since the raid on Arcos, Limited, Russia has deliberately confined her purchases from Great Britain to those goods, such as paper for electric cables, tool steel of the highest qualities, and so forth, which she cannot buy elsewhere, or which she can directly barter for exports. She will buy from Germany, Italy, America, Czecho-Slovakia, Austria, in preference to us. In no other country in the world—and it is necessary to remember this—would a political matter be allowed to exercise so much direct influence on trade. Our Government might be very huffy with the French Government over some matter of diplomacy, but in no imaginable circumstances would British traders be prohibited from dealing with France as a consequence. In Russia, however, it is impossible to separate business, diplomacy (or the lack of it), and politics. They are inter-related, because all foreign trade is in Government hands. Consequently, however much she may be needing our products, she will not buy them except where she cannot help herself, or where she can get longer terms of credit. Certain of the larger British firms have been trading steadily with the Soviets for many years without loss, and it is perfectly true that the Soviets have not once defaulted. But these firms know they are running a risk, and their prices are designed to cover them. To some extent, therefore, they are acting as their own bankers, financing their own enterprises. Some of them have consignment stocks in Russia in the care of certain Soviet Governmental trade organisations, which pay for them within a specified time after sale, or return the unsalable items. This, again, the smaller firms cannot do, especially as it usually involves the maintenance of a permanent representative and office in Moscow or elsewhere—a costly procedure. Business under existing conditions (the situation may have changed by the time this article appears) is, therefore, largely a matter of financial resources and willingness to take a risk.

DIPLOMATIC AND TRADE RELATIONS.

If situation No. 2 comes about, however, the position will be materially altered. It assumes that Russia will agree to recognise her private debts (the national or governmental debts will probably be allowed to cancel each other out, for the Russians, not unreasonably, claim damages from us for the destruction wrought by White armies, whom we provided with guns and ammunition), and make some effort at all events to pay them off or compound them. Payment in full is admittedly beyond her capacity. The moment this principle is conceded—and there is little doubt but that sooner or later it will be conceded—it is fairly safe to say that Russia will have access to the British money market. This means that she will be able to float a loan, with which to make purchases far more extensive than she has yet been able to do, and probably a principal condition of the loan will be that the major part of it shall be expended on British or colonial produce.

Trade relations of an active character will at once begin, and as private traders will be able to discount their Russian bills at a reasonable rate of interest, the execution of Russian orders will be attended by far less risk than is the case at present. This may seem a too optimistic picture, but it is not very far removed from the truth. The reader must bear in mind that in dealing with Russia then he will be dealing with a foreign government, not with a private firm, and with a government definitely pledged to honour its obligations. The only conditions on which he would run the risk of losing his money would be the chaos caused by a counter-revolution, the refusal of Russia to honour her financial obligations, or war between the two empires. As to counter-revolution, it can be declared almost dogmatically that there is not the slightest sign of any such event. Badly off as the Russian people are, they have had more than enough of revolution and fighting. They have been through seven years of acute hardship, and the thing they desire most (I speak now of the common people) is to get on with their jobs in peace, and do what they can to make a little comfort for themselves and their families. Discontent there may be, and to some extent is, but it is largely the grumbling discontent of people who know that there is not much chance of anything better at the moment, not the fiery resentment that leads to revolution. The Communist rule is strong and disciplined. The slightest disaffection is punished. And because the Bolshevik leaders are genuinely making an effort to get things straight, they are not wholly unpopular. In addition to all which, it must be remembered that the Red Army is solidly in favour of the existing *régime*, and without the army a counter-revolution could do nothing.

RUSSIA'S OBLIGATIONS.

A fresh refusal of Russia to honour her obligations would be equivalent to the suicide of the existing government, which they are not in the least anxious to commit. They have slowly and painfully built up some sort of order out of revolutionary chaos. They have got the machine going again, slowly and clumsily, but still going. They have made a few ambitious steps towards their own industrialisation. All these things they have only been able to do because people have been willing to give them a certain amount of credit. The moment they default again that credit collapses, and with it the economic structure of Soviet Russia comes toppling down. There would follow a state of chaos such as existed in China a few months ago followed by a similar decade of military brigandage, with

rival generals, red and white, chasing each other all over Russia. In any event, Russia as a market would be closed for years to British traders.

The Soviets know this as well as anybody else. They are by no means fools. And for this reason, any obligation into which they voluntarily enter is almost certain to be faithfully carried out, not because they have any greater regard for "bourgeois morality" than before, but because self-interest dictates this conduct.

STEPS TO MINIMISE PROPAGANDA.

A war between the two countries is equally unlikely. Russian propaganda has not been lessened by the Arcos raid. It has, rather, been intensified. And the surest way of minimising it is to make it worth while for Russia herself to take the necessary steps to this end. So long as she has nothing to hope or gain from England, she is likely to pursue her mischief-making policy wherever she can. If she has every reason to keep on good terms with her, she will take her own measures to achieve this. Russia is still the home of numerous "wild men," and from time to time there may be indiscretions by fanatical minor Communist clerks and officials, but these are unlikely to be serious enough to lead to war. The British Government and the British people have had enough of Archangel expeditions, and now that there are no longer White generals and admirals to support, it is difficult to imagine any British invasion of Soviet territory. As for Russia, she will have all her work cut out during the next fifty years to set her own house in order. She will have neither money nor time for militarist adventures. There is no parallel at all with revolutionary France. Russia has been industrially and economically crippled to an extent that France never was, and modern war is a vastly more exacting and costly matter than Napoleonic war.

RUSSIA OF THE FUTURE.

As for No. 3, it is difficult to forecast what Russia will be like in five years. At present, the Soviets are following out what is known as the "Five-year Plan," each year marking a successive stage in the increasing industrialisation of the country. The professed aim is to make Russia a self-supporting country—a second United States. The necessity for this is partly real, partly psychological. The prevalent and fostered communistic belief is that Great Britain stands at the head of a great capitalist conspiracy to draw an economic ring round Russia, and blockade her into a resumption of private enterprise. To defeat this object, it is essential that Russia should be able to support herself in every respect, so that she may exist utterly independently of capitalism. With the development of this theory has come a growing nationalism. The old Red theory that no country is more important than another, and that communism is a world movement, is gradually being replaced by "Russia for the Russians."

But while this theoretical argument for industrialisation is important, it is not nearly so important as the economic argument, which is based on actual necessities. The real driving force behind this attempt at a vast industrialisation of an illiterate and agricultural country is the insistent demand of the peasant for manufactured goods. The Soviets desire increased production of grain and timber. The peasant refuses to take the necessary steps and do the necessary hard work to this end, simply because when he goes to the shops to spend the money he has earned he cannot buy the goods he wants. The shops, even in towns like Moscow and Leningrad, carry notices: "No trousers to-day," or "boots expected from the factory next week." There are shortages of all sorts. The peasant's money being more or less useless, he sees no reason to exert himself to produce more than is necessary for his own requirements. The lack of an exportable surplus of grain and timber restricts the ability of the Government to obtain foreign currency in exchange for these exports. Their lack of foreign currency (Soviet money being of little value outside Russia) prevents them from purchasing desperately-needed imports. The lack of these imports holds up their schemes for big manufactories, and prevents their supplying the goods the peasant needs. It will be seen that this is a vicious circle, which can only be broken by obtaining ever longer credits from such foreign firms as will grant it, or by obtaining a large loan from some such country as Great Britain. But with every penny that they can get together, the Soviets are building enormous factories, factories of a size and on a scale such as probably only America can show. The writer has seen factories built since the Revolution that cannot be described without use of the words "beautiful" and "magnificent." And, what is more, these factories are working. Given a foreign loan, and the multiplication of these enormous factories would begin. It will be seen at once what an enormous scope for British goods the pursuance of this plan would offer.

SHORTAGE OF TRAINED MEN.

In many quarters, including Russia itself, it is considered that this plan of rapid industrialisation is too grandiose to succeed. It is pointed out that there is not a sufficiency of trained technical men to run the factories, of skilled management, of internal demand to absorb the products of the factories. But Russia is an incalculable country, and Stalin, Secretary of the Communist Party, and virtual dictator of the country, is definitely set upon the fulfilment of what he claims to be the policy Lenin left behind as a legacy. Russia has a population greater than that of America. She has economic resources greater than those of America (*i.e.*, the U.S.A.). Her leaders are doing their best to increase the standards of life of worker and peasant by education and propaganda. There is no saying what may be done between now and 1940. It is possible that, given moderation and commonsense on an ever-increasing scale among her leaders, she may in fifty years be one of the most prosperous and efficient of European nations. That is looking a long way ahead, but it is a distinct possibility.

Meantime, there is no doubt at all as to Russia's potentialities as a market. It will be as well not to exaggerage her capacity to absorb British goods, even in the event of her receiving a foreign loan. Some ridiculous figures have been quoted here and there in the British Press. And a change of Government in this country might again cast sand into the machinery of trade and lead to fresh disturbance. A second Arcos raid would, almost certainly, be fatal. But Russia cannot now (as she could be five years ago) be more or less ignored as a market for British goods.

MANUFACTURE OF IRON ORE.

Among the organisms that crowd the thin terrestial crust of land, air, and water, to which they and we are rigidly confined, incomparably the most numerous are invisible to our unaided eyes. They are among the most formidable, as well as the most necessary, of the natural agencies with which man has to reckon. These remarks are made by Earl Balfour in his preface to the System of Bacteriology, the first part of which has been issued by the Medical Research Council. We are familiar enough with the harm done by bacteria in attacking and disintegrating every kind of building material except concrete. We know the taste the iron bacteria have for the inside of water conduit pipes, each organism taking its little bit of iron and converting it into rust, which is nothing more than the accumulated corpses of sated bacteria. But it is a new conception that without bacteria we should have no iron ore. The American geologist, Harder, has detected the remains of iron bacteria in all the ochre deposits he has examined. From time immemorial the iron bacterium has sought out the traces of iron in the terrestrial waters, has stored them up in its sheath, and, dying of repletion in its millions, has left deposits of iron ore which can be worked for the metal. Similarly without bacteria we should have had no coal or peat, and probably no mineral oil.

Reviews of Current Literature

BLAST-FURNACE PRACTICE.

Mr. Clements, who is actively engaged in the iron and steel industry, is to be congratulated on the very efficient manner in which he has assembled his facts. It is significant that he has not only drawn from his own wide experience, but has made excellent use of the experience of a wide circle of furnacemen throughout the world. The subject of these books, therefore, is not confined within the limits of national barriers, but has been written with full recognition of its world-wide importance. This is necessary because the demand for iron in the future, either directly or in the form of steel, will encourage the installation of other producing units in centres of the world where at present little is being done. Increasing population and fresh applications of iron, or its modified forms, in structures and machinery, and, in addition, the continued developments of new countries, necessitate an international survey, and the value of these volumes is increased in consequence.

The scope of this work is not confined to the blast furnace, important as this undoubtedly is, but it covers the complete installation necessary. It is obvious that the complete success of the blast furnace can only be assured when it is supplied with ore of suitable character, from both a chemical and a physical standpoint, fluxes of right quality, fuel of suitable size, strength, and composition, blast at a suitable pressure and temperature, and the whole operated and controlled by a competent staff. In this survey the author gives full consideration to all the conditions that lead up to the blast furnace, before production, and away from it after production. In the first volume Mr. Clements considers primarily the source of the raw materials, their preparation and means for transporting them from their source to the blast-furnace plant, and the mechanism involved in each section.

Pig iron is the heterogeneous mixture of several elements and compounds formed between iron and its various impurities, and because of its complex character the author gives a preliminary survey of its metallurgical properties at the outset, together with the functions of the blast furnace and the chemical principles involved.

The final result in a blast furnace is, of course, fundamentally due to chemical interchange, yet the nature of reactions is largely governed by the thermal and physical conditions to which the reacting substances are subjected, and many of the reactions are reversible unless the requisite conditions of continuous reduction are maintained. The thermal and physical conditions are adequately discussed in the preliminary chapters, but the first volume deals primarily with the character and geographical distribution of available iron-ore deposits and their preparation for smelting. Our knowledge of the earth's crust is limited to a relatively small depth, but all the elements known to chemical science are found in it. Iron exists with other elements forming compounds, and is one of the most widely distributed metals occurring in varying degrees of richness. Mr. Clements has not only given a very extensive survey of the principal iron-ore deposits and districts that are at present productive, but has also indicated those that are prospective and which will offer possibilities in the future. The more important deposits are considered with the aid of illustrations, the character of the ore, method of working the mines, and the machinery used, being examined in detail in order to emphasise the principles involved.

The development of the blast furnace is largely due to improvements from the use of modern blast-furnace coke; the production of coke is carefully considered by Mr. Clements, and typical examples of plant have been selected to illustrate the processes. The manufacture of the ideal coke for blast-furnace purposes has involved much research work; even at the present time, investigations are being carried on with reference to the chemical composition and physical structure of coke by the Fuel Research Board, as well as many independent workers. Not so long ago the chemical composition was regarded as the only standard, but it has now been recognised that the physical properties of the fuel are as important, if not more so, as the chemical analysis. Much depends upon the quality and cost of the coke, for the blast-furnace industry can only prosper on the production of a large quantity of pig iron at low cost.

Probably in no other industry does such tremendous weight of materials enter so closely into the economy of production as in the production of pig iron. The vital importance of rapid handling and transporting the ores, fluxes, and fuel to the plant, and subsequently at the plant, together with the iron and slag produced, cannot be over-estimated. The mechanical means involved are described, and excellent illustrations simplify the reading of the text.

The basis of the second volume is a consideration of the design and equipment of the blast furnace plant. Mr. Clements considers that, in the general layout of the plant, simplicity and uniformity should be the keynote, and each furnace should be arranged as a separate unit with its own stoves, hot blast main, cold blast main, and blowing machinery. This is desirable when laying down a new plant, but modifications to existing plants make for complications that do interfere with its original simplicity. In the layout of blast-furnace plant it is advisable to take a long view and make arrangements for possible expansion, particularly with regard to transporting facilities. The general tendency to-day is to modify the design and increase the capacity of each furnace, which considerably increases the weight of material to be handled, and, unless the transporting facilities can be adjusted to cope with the increased loads, they become a serious handicap to the working capacity of the plant. Rearranging for transport so that it will adequately cope with the additional burden to be carried may be more difficult than modifying an old plant to cope with modern conditions. Economical considerations, however, require a larger output per unit in modern practice.

In dealing with the furnace and its working, nothing is more important than the regular distribution of the charges. In his consideration of this subject, Mr. Clements does not attempt to be dogmatic in his views; in his reference to skip and bucket distributors, for instance, advantages and disadvantages of each form are given for comparison, so that the reader may draw his own conclusions. All blast-furnace operators agree that correct distribution is so essential to the success of the furnace that it is worth while to install the very best mechanical contrivance which ensures it; hence the merits of the various methods used are given careful consideration. The adoption of mechanical charging has led to such an improvement in conditions at the top of the blast furnace that there is little more inconvenience arising in such a location than in many other instances on the ground level. This fact has to be borne in mind when the relative merits of the bucket and revolving distributor are being considered, but a big variety of designs of each type is given, which enables the reader to grasp their merits in comparison with varying conditions that are necessarily involved.

Crude gas systems, together with the provision and distribution of the air blast, are given ample consideration, the various systems and the various types of blowing engines are described, and the advantages and disadvantages of each referred to, not so much to enable the reader to determine which is best under any circumstances, but to form a guide in determining the relative qualities of each under varying conditions. In addition to a very complete consideration of all the sections and machinery that comprise the complete blast-furnace plant, the second volume concludes with a very valuable chapter on pyrometers and other instruments which are necessary in the full equipment. The value of the information gained from the use of pyrometers, gauges, and meters enables the highest economy to be attained, which may make all the difference between profit and loss.

To all engaged in the iron and steel industry these volumes will prove invaluable; the subject-matter is well written, and the illustrations are excellent. It has been admirably planned, and the photographs, maps, plans, diagrams, tables, and working schedules have been arranged to make the volumes what they are—if we assume the third volume to be as good as the volumes under review,—a comprehensive work dealing with all the phases of this vast and complex subject.

One cannot resist a word of praise for the publishers, who have apparently spared no expense in the production of this work, and the result does both author and publisher credit. We await with some degree of pleasure the concluding volume, which will, no doubt, deal with the operation of the blast furnace, and the subsidiary products, as well as pig iron, will be considered, and when complete the work will probably prove to be the most important that has been written in the iron and steel industry in our time.—C. A. O.

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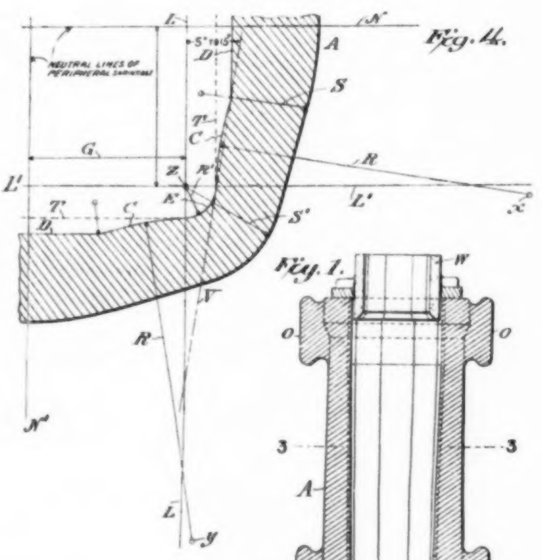

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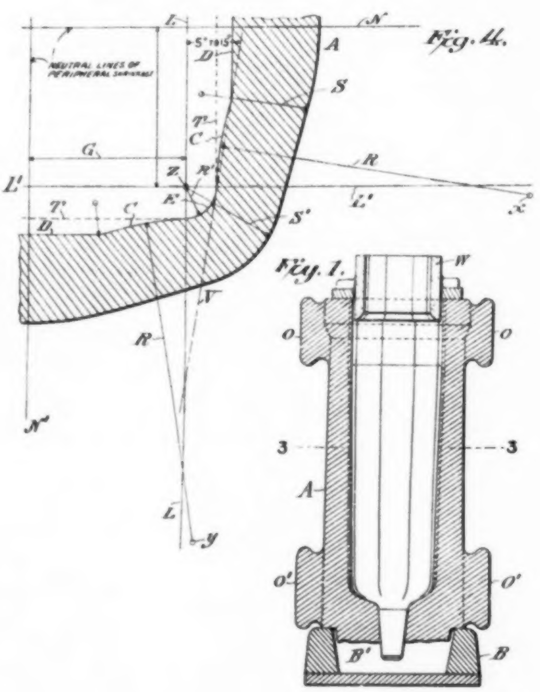

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metal thus obtained being mixed with the finely divided stock, which is charged at intervals into the chamber 2 through the opening 11. The apparatus may comprise a row of chambers 2 separated from a corresponding row of chambers 3 by a wall 5, the partitions between the several chambers of each row terminating slightly above the level of the charging and skimming doors 12, 14. The agitator comprises a grid secured to a vertical rod 37 by means of wedges 42, Fig. 6, which have projections 39 to engage in recesses 38 in the rod, and are formed with inclined outer faces which contact with the sides 36 of an upwardly tapering hole in the boss 32 of the grid. The rod 37 is protected by a casing 40, enclosing fireclay.

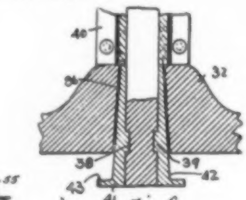


Fig. 6.

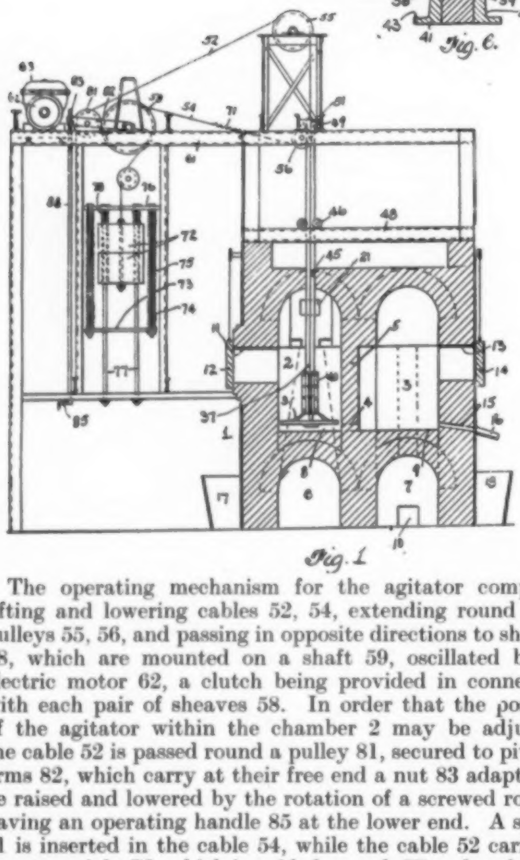


Fig. 1

The operating mechanism for the agitator comprises lifting and lowering cables 52, 54, extending round fixed pulleys 55, 56, and passing in opposite directions to sheaves 58, which are mounted on a shaft 59, oscillated by an electric motor 62, a clutch being provided in connection with each pair of sheaves 58. In order that the position of the agitator within the chamber 2 may be adjusted, the cable 52 is passed round a pulley 81, secured to pivoted arms 82, which carry at their free end a nut 83 adapted to be raised and lowered by the rotation of a screwed rod 84, having an operating handle 85 at the lower end. A spring 71 is inserted in the cable 54, while the cable 52 carries a counterweight 72, which is guided on rods 77 and cushioned at the ends of its travel by springs 78 on the rods 77, and springs 74 carrying a bar 73.

317,378. J. Schmeller, sen., patentee. Messrs. White, Langner, Stevens and Parry, agents, Jessel Chambers, 88-90, Chancery Lane, London, W.C. 2. Dated February 13, 1928.

REFINING IRON OR IRON ALLOYS.

In order to remove the last trace of oxygen from iron, steel, or alloys thereof, an alloy of lead and sodium, or a lead cartridge filled with sodium, is added to the molten iron or alloy. The alloy or the lead cartridge may be contained in a perforated iron container. Sodium may be replaced by any other suitable deoxidising agent, and the lead by any metal not detrimental to the iron alloys, and having a higher specific gravity than the molten iron.

317,493. A. Glazunov, Pribram, Czecho-Slovakia, patentee. Dated August 18, 1928.

IRON ALLOYS.

A new method of decarburising ferro-alloys, particularly ferro-chrome, ferro-manganese, and ferro-tungsten, has been devised. It consists in applying to the surface of the molten alloy, in a side-blown converter, a blast containing not less than 48% of oxygen, a temperature of at least 1,600° C. being maintained by oxidation of constituents of the alloy. The molten metal may also be blown with hydrogen either during or after blowing with the oxygen blast, and the hydrogen may be introduced below the surface of the metal. A rustless iron alloy may be made by diluting high-carbon ferro-chrome with molten steel, tapping the product into a side-blown converter, and blowing as above ; or a mixture of chromium ore with iron or steel or iron ore may be smelted and the product blown.

316,329. H. E. Potts, 12, Church Street, Liverpool. Dated March 27, 1928.

TREATING ORES.

Ores, slags, residues, or other materials containing base metals (other than tin and aluminium) such as zinc, lead, copper, iron, calcium, magnesium, or manganese, and which may also contain precious metals, may be treated with an admixture of dry ammonium chloride and gently heated, say, to 200–350° C., whereby chlorides of the metals present are formed, and ammonia, ammonium carbonate, or sulphur compounds of ammonia are evolved. Preliminary treatment of ores may comprise mass concentration, and removal of large amounts of dolomite, calcite, or iron. Soluble salts formed may be bleached out with water and fractionally precipitated from solution by means of ammonia with or without carbon dioxide, ammonium carbonate, or ammonium sulphides obtained in the reaction with recovery of ammonium chloride for re-use. Alternatively, hydrogen sulphide may constitute the precipitant. Water-insoluble salts formed may be bleached out with suitable reagents ; for instance, cuprous chloride by acids or ammonium carbonate, and lead chloride with acetic acid and ammonia, or with ammonium acetate, or with hydrosulphurous acid with ammonia, or with ammonium hyposulphite. From the resulting solution lead may be precipitated as oxy-chloride by neutralisation with ammonia or ammonium carbonate, or as chloride by hydrochloric acid, or as sulphide. Materials containing lead as sulphate may be pretreated to form lead carbonate and ammonium sulphate, and the product after removal of ammonium sulphate, and, if desired, also of lead carbonate, be treated with ammonium chloride. The lead chloride or oxychloride may be subjected to electrolysis, using a fused electrolyte, for instance, zinc chloride or lead sulphochloride $PbCL_2 3PbS$; or it may be reduced to metal by hydrogen.

When treating a complex sulphide ore containing zinc and other metals, such as copper and lead, the amount of reagent used may be such that all metals other than zinc present are chlorinated, whereby after removal of the chlorides formed a zinc sulphide concentrate is obtained. When zinc chloride is formed in the primary heat-treatment, using a controlled amount of ammonium chloride, it may be volatilised and recovered in an hydrous form by heating the product with exclusion of air and moisture to 750–900° C. When such means for recovery of zinc chloride is used, iron present in the initial material is preferably first reduced to the ferrous or metallic state, so that ferrous chloride only will be formed during chlorination, and will not volatilise with the zinc chloride. Lead chloride, if present, may also be volatilised at 900–950° C. Initial materials, such as lead and zinc bearing ores, may first be treated to volatilise the constituent metals as oxides, and the latter be subjected to the treatment with the ammonium salt.

E. A. Ashcroft, Waye House, near Ashburton, Devon, April 5, 1928.

Business Notes and News.

Olympia Extensions for British Industries Fair.

An additional building is being erected at Olympia to provide increased accommodation for the British Industries Fair next year. This addition, consisting of two floors, measures 330 ft. long, and is twice as high as the existing Olympia. It will be equipped with six high-speed "Talky" lifts, announcing the different floors automatically, thirty-six staircases and escapes, flood lighting for the front, and advertisement letters in stainless steel. Although there will be two floors still to complete, the whole front is to be finished for the opening day. It is noteworthy that it has been erected in three months, and that 6,500 tons of steel were required. The "Talky" lifts are to announce what is to be seen on each floor as the visitors go up or down. In addition, there will be two goods lifts with room for the largest motor-cars. Each floor provides an exhibiting area of about 50,000 sq. ft., bringing the total at Olympia, including the old buildings, up to nearly 600,000 sq. ft. In cubic content the new building will, in itself, it is stated, be the largest building in the Empire.

Fusion of Interests.

Messrs. Dorman, Long and Co., Ltd., by absorbing the firm of Messrs. Bolckow, Vaughan and Co., Ltd., form a fusion of interests, and will result in the creation of a great iron, steel, and coal-producing corporation controlling about a quarter of the steel-producing capacity of the country. These companies are parallel with each other in equipment, in control of the raw materials of steel production, and in the markets they supply. It is claimed that their joint power of production will be based upon a well-balanced supply of raw materials and a more efficient use of plant. Concentration of work in the most economical units, with the subsequent reduction in cost, will, it is stated, enhance the earning powers. Co-operation between the structural and bridge building businesses of both firms is likely to ensure for the joint concern a predominant position in constructional engineering. The negotiations have occupied practically two years, and various difficulties had to be overcome before the final settlement of the terms of fusion could be agreed upon.

Metal-divining.

A metal-divining invention which, it is claimed, was associated with the recent developments at the Mill Close lead mines at Darley Dale, threatens to revolutionise the metallurgical world. This instrument is claimed to indicate the presence of metals 1,000 feet below the surface. The invention is due to Mr. Franklin, headmaster of Stancliffe School, at Darley Dale, with whom Dr. Chapman, headmaster of the Ernest Bailey Secondary School at Matlock has associated in perfecting the device. Tests have been made in Durham, where it is stated a deep-seated metal deposit has been located. Tests in Peakland have been made near Bakewell, Monyash, and Youlgreave. At Youlgreave, where the device was tried at a lead mine, the apparatus, it is stated, showed the futility of expecting a lead vein beyond a certain point. The owners of the mine were sceptical, but on investigation they found the indication to be correct.

Economic Difficulties in Wrought-iron Industry.

The causes of the difficulties with which the wrought iron industry was faced were economic rather than connected with manufacture, said Col. J. S. Trinham, before the members of the Staffordshire Iron and Steel Institute. However regrettable present conditions might be, the industry was not dismayed by the bogey of foreign competition, particularly if users would realise the vast difference in quality between iron of British manufacture and iron of foreign manufacture. Within the last five years the leading firms of the industry have made unceasing efforts to maintain their position, both by improvements in the product, in market and advertising their goods and by reductions in cost. The cheap mixture of iron and steel had unquestionably done great harm to the British iron trade. It was altogether a question of lower price, but the inferior character of much that was sold as "iron" had involved genuine wrought iron to be given the same condemnation.

Vanadium and Titanium in Pig Iron.

In all work, on the addition of special alloying elements to cast iron, it has long been realised that the addition of vanadium is especially valuable. The high cost of this ferro-alloy has prevented its use in the ironfoundry. A new form of pig iron, known as Norskalloy, has now been produced exclusively from ores containing a quantity of vanadium and titanium, which offers a cheap and convenient method of adding vanadium to a charge. The pig iron is available in small sand-cast pigs to the following typical analysis :—

	Standard. %	Refined. %
Total carbon	0·4 to 4·5	2·5 to 3·5
Silicon	0·5 ,, 1·5	0·70 ,, 2·5
Manganese	0·20 ,,	0·50 ,, 0·80
Sulphur	Trace	Trace.
Phosphorus	0·20 ,, 0·25	0·15 ,, 0·20
Vanadium	0·30 ,, 0·40	0·20 ,, 0·30
Titanium	0·40 ,, 0·80	0·30 ,, 0·50

In addition to the above constituents careful investigation has shown traces of other rarer elements, such as beryllium, while, if required, nickel and chrome can be added. This new pig iron has a low sulphur content, and the phosphorus is sufficiently high to ensure the necessary degree of fluidity and castability for foundry purposes. In use the addition of 15% to 20% of the pig iron to a mixture is recommended for most purposes where vanadium is desired. It is claimed that vanadium tends to stabilise the carbide in grey iron castings, and gives improved wear-resisting properties. Experimental work in Germany and United States is claimed to have shown beneficial results from the use of vanadium and titanium in malleable-iron castings.

New Thames Bridge.

A new bridge at Lambeth, in five spans, 60 ft. in width and with 12 ft. pavements, is being erected in place of the present three-span suspension bridge across the Thames. The time of construction is estimated at three years, including the erection and subsequent removal of a temporary footbridge, the demolition of the old bridge, and the construction of the new one. It is also required that the whole of this work shall be carried out without interference with the river traffic. About 3,500 tons of steel will be used for the new bridge, the centre span of which will be 165 ft. long, each intermediate span 149 ft. long, and each approach span 125 ft. long. The four supporting piers will be constructed on steel caissons sunk by means of compressed air to a solid foundation about 25 ft. below the river bed. A point of interest in the construction of the approaches leading up to the bridge is the proposal to raise three hundred yards of embankment, between the Tate Gallery and Lambeth Bridge by 7 ft. It was along this reach that severe damage was done by the disastrous Thames floods in January, 1928. This new undertaking is being carried out at a cost of £555,000 by Messrs. Dorman Long and Co., Ltd.

British Tin-research Activity.

Although tin is the most ancient of all metals to be used as an alloy, dating back to the Bronze Age, no comprehensive research has ever been made into its unique properties. The commercial value of such research is well illustrated by a recent discovery. It has been found that by mixing a small amount of tin with lead, and adding a smaller quantity of another non-ferrous metal, the strength of the lead was increased enormously, as was its resistance to corrosion and cracking. This new alloy will mean the saving of many hundreds of thousands of pounds a year to the electrical industry and the building trades. Since the formation of the Tin Industrial Applications Committee was announced some time ago, the hon. secretary has had inquiries and applications for membership from almost every part of the world. American and British industries using tin are taking an active interest. The Committee are in close touch with many of the principal United States tin-consuming industries.

German Steelworks Report.

The United Steel Works Co., of Germany, has published a report for the year ending September 30. A slight increase in the production of coal and coke is shown, but the production of pig iron and raw steel has decreased. Pig iron production was 6,000,000 tons, and that of raw steel 6,420,000 tons, the total turnover amounting to £71,667,900, or £216,450 less than in the previous year.

Business Notes and News—continued.

New Water Scheme.

The South Durham Steel and Iron Co. have secured a contract for steel pipes for the Grampians hydro-electric supply scheme. In this scheme the water for driving the turbines will be drawn from Loch Ericht at an altitude of 1,150 feet, and brought to a point on the shores of Loch Rannoch, where the power station will be situated. The pipe line is 2,750 feet long and the pipes have a diameter of 94½ in. This pipe line will constitute the largest diameter of welded-steel pipe ever manufactured.

Fusion of American Steelworks.

An important move towards the formation of a new group in the United States steel industry is indicated by the merging of the Interstate Iron and Steel Company of Chicago with the Central Alloy Steel Corporation of Ohio. This merger, which is regarded as a nucleus for a big consolidation of alloy and special steel concerns to be formed later, will bring the assets of the Central Alloy Steel Corporation to a total of over £18,400,000. This corporation recently acquired rights to produce in America certain valuable new alloys developed by Krupp in Germany.

Rights for "Elektron" Alloy.

The Birmingham Aluminium Casting (1903) Co., Ltd., are breaking new ground in several directions and have organised a chemical engineering department. This company together with the Stirling Metals, Ltd., have the sole rights for the new "Elektron" alloy. It is a magnesium alloy which is 40% lighter than aluminium, having the same physical characteristics as aluminium, and particularly suited for castings in which lightness is a consideration. This company have also acquired the exclusive right to manufacture Bohnalite pistons in this country.

The International Steel Cartel.

The future of the International Steel Cartel depends to an appreciable extent upon the solution of the domestic problems of the German industry. Whether the reconstruction problems will strengthen world steel prices remains to be seen. The recent fall in Continental steel prices was directly traceable to the previous uncertainty as to the future of the cartel, but it does not follow that the possibility of the reconstruction in a few months' time will reverse this trend. The next Council meeting of the International Steel Cartel is to be held at Dusseldorf on December 14. There is considerable satisfaction in French steel quarters that the uncertainty which has prevailed regarding its continuance has been removed.

Canadian Goodwill.

It is hoped that more orders will come to Great Britain from Canada now that Mr. J. H. Thomas has helped to create an atmosphere of goodwill between this country and the Dominion business interests. Many difficulties remain to be overcome, and consultative representatives of the National Federation of Iron and Steel Manufacturers have been appointed to confer with Mr. Thomas as and when occasions arise. The iron and steel trade representatives believe that much good has been done by creating an atmosphere which favours British products among Canadian buyers.

Foundry to Close Down.

It is proposed to close the Grimesthorpe foundry, formerly part of the Cammell Laird works at Sheffield, which was taken over by the English Steel Corporation. This steel foundry was modernised and enlarged about two years ago. It is equipped for the manufacture of ship and general castings of all classes up to 100 tons, or in ingot form for forgings up to 175 tons. The closing of the Cyclops works of the Cammell Laird section of the English Steel Corporation is now well advanced.

Investigations in Steel Structures.

An important investigation into the appreciation of modern theory of structures to the design of steel structures is to be made by the Department of Scientific and Industrial Research at an early date. It is expected that the investigation will be the most thorough ever undertaken, and may last several years.

Some Contracts.

The General Electric Co., Ltd., Kingsway, London, have been awarded in the face of severe competition a contract for the complete electrical equipment of a rolling stock covering the motors and control gear for a total of 46 motor-coaches. The contractors for the rolling stock are the Metropolitan, Cammel Carriage, Wagon, and Finance Co., by whom the contract for the electrical equipment was placed with the General Electric Co. The contract for the construction of the first unit of a large fibre-cutting steel plant in Burmady, British Columbia, has been awarded by the British Dominion Co. to the E. J. Ryan Contractors' Company for £500,000. Work on the plant will start shortly.

It is stated that the English Steel Corporation have been awarded an order to supply eight reaction chambers for plant being made for the Anglo-Persian Oil Co. This is claimed to be the first time such an order has been placed in this country. These reaction chambers are stated to be about 45 ft. long, 5 ft. in diameter, and 4 in. in thickness, and are to be made of high-grade steel. In order to ensure quick delivery, this Corporation is able to manufacture simultaneously in its three main steelworks.

Messrs. Beyer, Peacock and Co., of Gorton, Manchester, have received an order for two Garratt locomotives for Kenya and Uganda Railways. This makes a total of 26 locomotives of this type supplied to the railway by this firm.

An important contract has been secured by Vickers-Armstrong, of Barrow-in-Furness, for the machinery for a large cement plant in the Far East. The contract has been obtained from the Green Island Cement Co. The new works will consist of two units, each having a capacity of 1,000 tons of cement per week, giving a yearly output of approximately 100,000 tons.

The contract for the erection of the transmitter building has been secured by the Anglo-Scotch Construction Co., Ltd., Victoria Street, Westminster. This refers to the North of England original broadcasting transmitter for the B.B.C. at Monside Edge, Slaithwaite, near Huddersfield.

It is stated that the Egyptian State Railways have placed an order for rolling stock repair material with the Tees-side Bridge and Engineering Works, Middlesbrough, and we understand that Thomas Perrins, of Stourbridge, have secured the contract for sling chains from the same department.

It is reported that the work on the construction of the new aerodrome at Thornaby-on-Tees has been commenced. The Government recently purchased 200 acres of land for this purpose.

A contract for 56 steel electric motor bogie coaches has, it is stated, been secured by the Metropolitan Cammell Carriage, Wagon and Finance Co., of Birmingham. These coaches are for service on the underground railway now under construction in Buenos Aires, and are to be supplied to the order of the Buenos Aires Central Railroad and Terminal Co. The value of the order is stated to be about £250,000.

The supply of cast-iron pipes and irregular castings during the next six months for the Metropolitan Water Board has, it is stated, been awarded to the Stanton Ironwork Co. and the Butterley Co., both of Nottingham.

The order for twelve three-cylinder compound passenger tank locomotives for Argentina has, it is stated, been received by Robert Stevenson and Co., of Darlington. The engines are said to be of the 4-6-4 type, and are to be built to a new design; in full working order each engine is expected to weigh about 120 tons.

The New Zealand Railways are stated to have placed an order for five Leyland motor-bus chassis and five Thorneycroft chassis.

Machine tools for the new workshops of the Egyptian Ports and Lights Administration at Alexandria are, it is stated, to be supplied by Agricultural and General Engineers, Ltd., London, J. Bennie, Ltd., Glasgow, and Loudon Bros., Ltd., London.

Wallwork

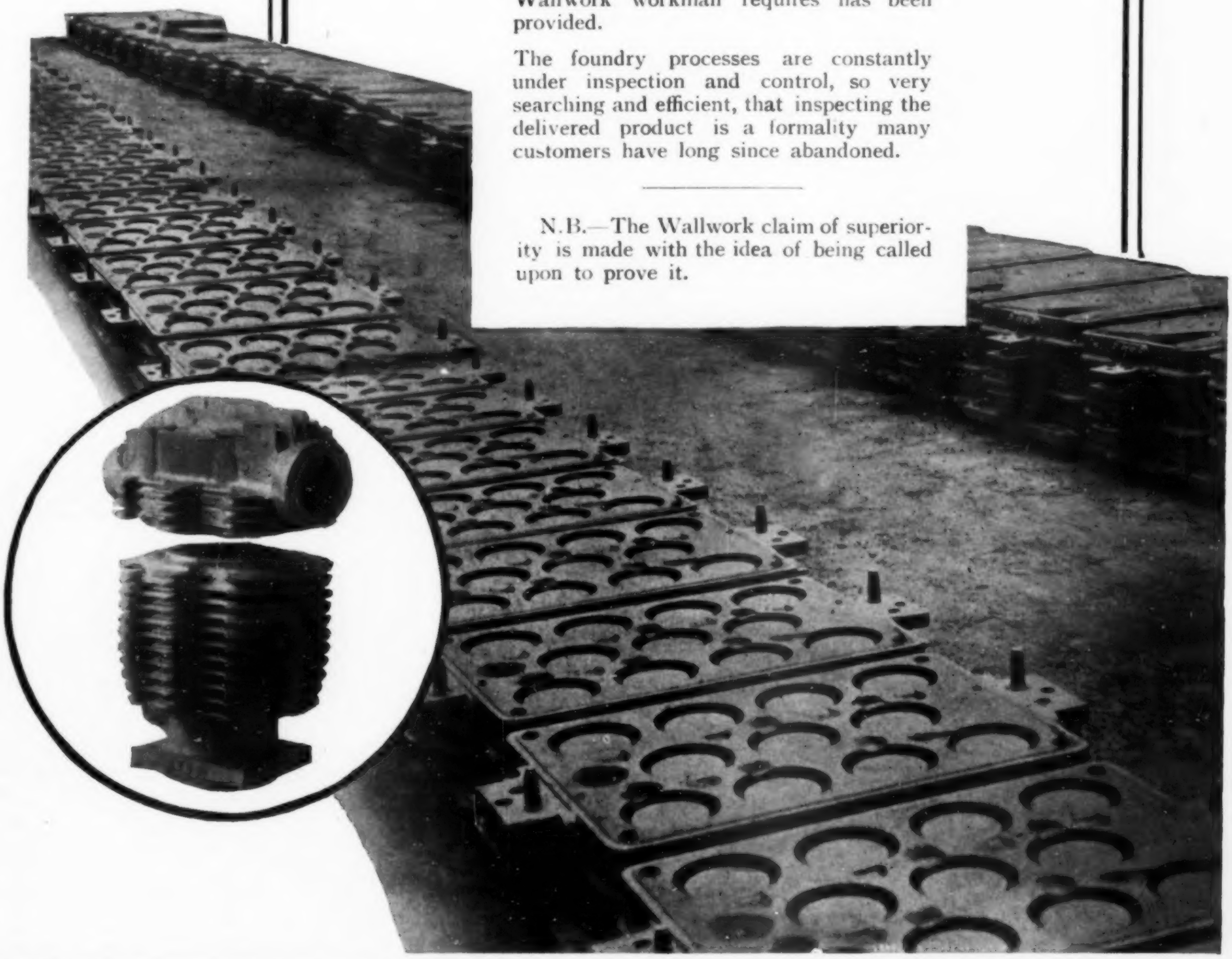
CONSISTENCY IRON CASTINGS

SINCE the day our first casting left the foundry the name Wallwork has advanced without a falter, till it has become the proudest name associated with the production of high quality castings.

Complete and modern equipment is a Wallwork advantage. Everything a Wallwork workman requires has been provided.

The foundry processes are constantly under inspection and control, so very searching and efficient, that inspecting the delivered product is a formality many customers have long since abandoned.

N.B.—The Wallwork claim of superiority is made with the idea of being called upon to prove it.



HENRY WALLWORK & CO., LTD., MANCHESTER.

MARKET PRICES

ALUMINIUM.

99% Purity		£95 0 0
Castings, 2L5 Alloy	lb.	1/3–1/8
„ 2L8 „	„	1/4–1/9
„ Silicon „	„	1/6–2/-

ANTIMONY.

English		£50 0 0
Chinese		35 15 0
Crude		20 15 0

BRASS.

Solid Drawn Tubes	lb.	12¾d.
Brazed Tubes	„	14¾d.
Rods	„	12¼d.
Wire	„	10¼d.

COPPER.

Standard Cash		£66 2 6
Electrolytic		82 0 0
Best Selected		74 15 0
Tough		74 5 0
Sheets		110 0 0
Wire Bars		84 0 0
Ingot Bars		—
Solid Drawn Tubes	lb.	15d.
Brazed Tubes	„	15d.

FERRO ALLOYS.

Tungsten Metal Powder	lb.	£0 3 6½
Ferro Tungsten	„	0 3 3½
Ferro Chrome 4% to 6% carbon	unit	0 7 6
Ferro Chrome 6% to 8% carbon	„	0 6 6
Ferro Chrome 8% to 10% carbon	„	0 6 0
Ferro Chrome 1% carbon	lb.	15d.
Ferro Chrome Carbon Free	„	14d.
Metallic Chromium	„	£0 2 6
Ferro-Vanadium	„	0 12 10
Ferro-Silicon 25%		—
„ „ 50%	unit	0 5 0
„ „ 75%	„	0 7 0
„ Molybdenum 75%	„	0 1 2
„ Titanium		£170–175
„ Nickel		—
„ Cobalt	lb.	0 9 4
„ Manganese loose		13 10 0
„ „ Export		14 0 0
„ Phosphorus 25%		16 0 0

FUELS.

Foundry Coke—		
S. Wales Export		£1 15 0
Sheffield „		1 3 6
Durham		1 7 6
Furnace Coke—		
Sheffield Export		1 3 6
W. Wales „		1 10 6
Blast-Furnace Coke, at ovens		0 14 6

GUN METAL.

Commercial Ingots		£71 0 0

LEAD.

Soft Foreign		£22 1 3
English		23 15 0

MANUFACTURED IRON.

Scotland—		
Crown Bars		£10 5 0
N.E. Coast—		
Rivets		11 10 0
Best Bars		11 5 0
Common Bars		10 15 0
Lancashire—		
Crown Bars		10 15 0
Hoops		13 0 0
Midlands—		
Crown Bars		10 5 0
Marked Bars		12 10 0
Unmarked Bars		—
Nut and Bolt Bars		9 2 6
Gas Strip		11 2 6
S. Yorks.—		
Best Bars		11 10 0
Hoops		12 0 0

PIG IRON.

Scotland—		
Hematite		4 0 0
Foundry No. 1		3 18 6
„ No. 3		3 16 0
N.E. Coast—		
Hematite		3 19 0
Foundry No. 1		3 15 0
„ No. 3		3 12 6
„ No. 4		3 11 6
Cleveland—		
Foundry No. 3		3 12 6
„ No. 4		3 11 6
Silicon Iron		3 14 0
Forge No. 4		3 11 0
N.W. Coast—		
Hematite		4 9 6
Midlands—		
N. Staffs Forge No. 4		3 15 6
„ Foundry No. 3		3 19 6
Northants—		
Forge No. 4		3 11 0
Foundry No. 3		3 15 0
Derbyshire Forge		3 14 6
„ Foundry No. 3		3 18 6
West Coast Hematite		4 9 6
East „ „		4 8 6
Swedish Charcoal Pig		6 5 0

PHOSPHOR BRONZE.

Rods	lb.	1/5
Tubes	„	1/9¼
Castings	„	1/4
Strip	„	1/4
Sheets 10 W.G.	„	1/5

SCRAP METAL.

Copper Clean		£65 0 0
„ Brazier		58 0 0
„ Wire		—
Brass		44 0 0
Gun Metal		58 0 0
Zinc		15 10 0
Aluminium Cuttings		64 0 0
Lead		20 0 0
Heavy Steel—		
S. Wales		3 14 3
Scotland		3 12 6
Cleveland		3 5 0

SCRAP METAL—continued.

Cast Iron—		
Lancashire		£3 6 0
S. Wales		2 19 0
Cleveland		3 7 6
Steel Turnings—		
Cleveland		2 17 6
Lancashire		2 17 6
Cast Iron Borings—		
Cleveland		2 13 6
Scotland		2 15 0

SPELTER.

G.O.B. Official		—
Hard		£19 0 0
English		22 2 6
India		20 0 0
Re-melted		20 0 0

STEEL.

Ship Plates (Scotland)		£8 12 6
„ „ (N.E. Coast)		8 12 6
Boiler „ (Scotland)		10 0 0
„ „ (N.E. Coast)		10 0 0
„ „ (Midlands)		9 12 6
Sheets ⅛ in.		—
„ 20 W.G.		11 15 0
Angles (N.E. Coast)		8 2 6
„ (Midlands)		8 12 6
Joists		8 2 6
Fish-Plates		12 0 0
Heavy Rails, N.W. Coast		8 10 0
Light „		8 17 6
Sheffield—		
Siemens Acid Billets		9 10 0
Hard Basic		9 7 6
Medium Basic		7 17 6
Soft Basic		7 0 0
Hoops		10 0 0
Manchester—		
Hoops		9 0 0
Bridge and Tank Plates		8 17 6
Billets		—
Channels		10 5 6
Bars, Mild Steel		—
Flat Bars		8 12 6
Tool Steel—		
Finished Bars 18% Tungsten	lb.	2/9
Round and Squares	„	3½d.
Under ½ in.	„	3d.
Round and Squares 3 in.	„	4d.
Flats under 1 in. × ⅜ in.	„	3d.
„ „ ½ in. × ¼ in.	„	1/-

TIN.

Standard Cash		£176 5 0
English		177 0 0
Australian		181 0 0
Eastern		187 0 0
Tin Plates I.C. 20 × 14	box	18/10½
Block Tin Cash		£178 0 0

ZINC.

English Sheets		£30 10 0
Rods		34 0 0
Battery Plates		28 0 0

TRADE CATALOGUES AND PUBLICATIONS.

A booklet describing the products of the United Steel Companies, Ltd., is now available. The activities of this company cover the entire field of iron, steel, and engineering production. It consists of a grouped organisation by which successive and interdependent industrial processes are linked into a single unit. The booklet gives some idea of the wide variety of products manufactured by the constituent firms that form the group, and can be obtained from United Steel Companies, Ltd., 17, Westbourne Road, Sheffield.

Two brochures have been received having special reference to the recent non-ferrous alloy discovery of Messrs. Vickers-Armstrongs, Ltd., of Barrow. The alloy is known as P.M.G., and one brochure relates particularly to the use of this alloy in the making of castings in comparison with brass and bronzes. The second brochure contains information of a more general character, indicating the value of the alloy for forging and extrusion, and including tests to support the merits of the alloy. The result of experimental tests on its anti-friction, resistance to corrosion and erosion, high temperature service, are included, together with sweating tests.